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# SELECTED WRITINGS ON freeze-drying of foods

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U. S. DEPARTMENT OF AGRICULTURE • ECONOMIC RESEARCH SERVICE • MARKETING ECONOMICS DIVISION • ERS-147

## PREFACE

This report contains a collection of speeches, articles, and informal papers on freeze-drying by Kermit Bird, Agricultural Economist, Marketing Economics Division, Economic Research Service. They were written between August 1962 and August 1963, and were originally designed for internal Government use and limited public distribution.

The speeches were made before a variety of audiences, usually at meetings of professional organizations, such as assemblies of agricultural economists and heating, refrigerating, and air-conditioning engineers. The articles were published in periodicals of the U. S. Department of Agriculture and the Oklahoma Extension Service.

Except for correction of typographic errors, the original wording of all but one of the papers is retained in this report. This one is revised here to include shipping and storage costs.

Note concerning costs: The costs quoted in the above items were preliminary. They have been slightly revised. For latest cost estimates, see "Freeze-Drying of Foods: Costs Projections," U. S. Dept. Agr. Mktg. Res. Rpt. 639, Dec. 1963.

Other freeze-drying reports available from the Department include:

Freeze-Dried Foods: Palatability Tests. Mktg. Res. Rpt. 617, 36 pp., July 1963.

Freeze-Drying of Foods: A List of Selected References. Library List 77, 79 pp., July 1963.

Freeze-Drying of Food -- A Look into the Future. ERS 134, 7 pp., August 1963.

Single copies of these reports are available from the Division of Information, Office of Management Services, U. S. Department of Agriculture, Washington, D. C. 20250.

Washington, D. C. January 1964

SELECTED WRITINGS ON FREEZE-DRYING OF FOODS

By Kermit Bird

Marketing Economics Division
Economic Research Service

# FREEZE-DRYING - PROGRESS AND PROBLEMS

Presented at meeting of Western Farm Economics Association, Reno, Nev., August 1962. (F-D Report No. 1)

"Freeze-drying is the newest thing in the dehydration world."

"Freeze-drying will be a $2 billion, or a 4 billion pound business by 1970, investment advisory service predicts."

These two quotes are not mine. They were taken from recent articles in trade magazines and serve to illustrate the manner in which freeze-drying is tickling the imagination of food processors. A vice-president of one of our large food companies puts it this way:

"Men in the food processing industry are forever optimistic. They hope for a revolutionary processing innovation that will give the whole industry a boost. Right now, many processors feel freeze-drying is their panacea."

*Is there a real growth potential in this new industry?

*Will freeze-drying ever become a commonly used processing method for food?

*What foods appear to be most adapted to this drying technique?

*Who are potential users of freeze-dried products?

*Will freeze-drying be substituted for other processing methods, or will it be used in addition to present methods?

These are good questions, but complete answers are not available.

## What is Freeze-Drying?

Let us define freeze-drying so our thinking is channeled along the same lines. Here is an industry definition:

"Freeze-drying is a unique food preservation process that removes moisture from frozen foods without appreciably changing the shape, color, or taste of the product. Cellular structure remains intact. With the water removed, the food can be stored for long periods of time without refrigeration. Moreover, the freeze-dried product loses 75% to 90% of its weight in the process. Reconstitution is accomplished by simply adding water or any other liquid."

To this, I would add that the dried product has a high attraction for water and oxygen. It must be carefully packaged to prevent re-entry of these into the product. Bacterial action is kept to a minimum because of a lack of these two.

Basically, it is changing frozen foods (either cooked or uncooked) to the dry state by sublimation. This means that ice in the frozen product goes directly from solid to vapor, bypassing the liquid phase. This process takes place in a vacuum chamber at very low pressure and with a controlled input of heat. Foods emerge sponge-like, and the resulting "voids" aid in rehydration. Since only distilled water leaves the product, the oils and other carriers of flavors remain. The flavors also remain.

Although the technique is not new, processing innovations in recent years have lowered costs sufficiently so that now it is being considered as a food preservation method. It has been used for many years in the medical and drug fields, with blood plasma as a prime example.

## Processing Techniques

The first step in freeze-drying is preparation of the food. This is an important key to good quality end products. The procedure used depends largely on the product, although all products need to be sliced, diced, granulated, powdered, or liquefied to keep the cycle time to about 8 hours. The food is frozen and these frozen foods are placed on trays, about 2 to 3 pounds per square foot. Loaded trays are placed in a freeze-dry cabinet and the air pumped out of the cabinet. Heat is applied between the trays to the food, and the sublimination process takes place -- always at temperatures below the melting point of the product. When the core of ice within the product has disappeared, temperature of the product rises, and moisture level of the product has been reduced to 2 percent. It is now freeze-dried. The cabinet is back-flushed with nitrogen; the product is removed from the cabinet and goes to the final stage -- packaging. Most products now on the market are nitrogen packed, although vacuum packing is used. Both cans and flexible pouches are being used as packages. Cans, however, appear to have an advantage in that they offer better protection to the friable product; and a satisfactory seal is easy with a can but difficult with a pouch.

## Characteristics of Freeze-Dried Products

Under proper conditions, freeze-drying preserves much of the structural, chemical, and physical integrity of foods. With the exception of freezing, this process comes closer to maintaining original product characteristics than any other processing method. This is a primary advantage of the method. In our taste-panel work, we are using both frozen and canned foods as standards of comparison.

Final products of the process are dehydrated, not frozen. As such, they may be kept in room temperature storage over long periods of time with minimum deterioration. Length of storage period depends of the quality of the original raw product, care with which they were freeze-dried, and seal of the container. They should be good for 2 years at room temperature.

Another aspect of the product is its lightness of weight. For example, if we were marketing raw, deboned chicken meat, for every 100 pounds of frozen product we could ship only 29 pounds of freeze-dried product. With 100 pounds of mushrooms, we would ship only 11 pounds of freeze-dried product, 11 percent of the original weight. The lightness of the product is somewhat offset by the weight of the container. With some foods, can weight exceeds product weight.

Undesirable characteristics of the product might include appearance. Many foods, especially meats, look quite unappetizing without their natural moisture. Thus, a package with a window probably will not be used for these products. The affinity for water might be listed as a disadvantage also, since it makes packaging especially difficult and costly. On the other hand, it is this same characteristic that is a distinct advantage since it enables the food to be rehydrated much more quickly and completely than other dry products. The necessity to nitrogen or vacuum pack may also be listed as a disadvantage.

It is not necessary to rehydrate these freeze-dry foods with water. For example, strawberries could easily be rehydrated with syrup, meats with water to which tenderizer has been added, and fish with water and lemon juice. There is no technical reason why any product could not be rehydrated with beer, wine, rum,

or other spirits. This thought adds an exotic dimension to the potential use of these products.

## Products That Appear to Have Commercial Application

Presently we have in this country about seven companies with products on the market. Two meat companies have lines of campers' foods. These include sausage, beef steak, swiss steak, hamburgers, pork chops, ham and eggs, scrambled eggs, chili and beans, chicken dices, green beans, peas, and shrimp creole. All these products are cooked, and hot water may be used in rehydration. This line of camper foods may be a way of testing the market, because campers are only a tiny part of the total food market. Two prominent soup companies use freeze-dried components in their dried soups. Products are chicken and beef dices, onions, and mushrooms. Another firm is currently marketing, for the institution trade, shrimp, chicken, and crab. On the West Coast two firms do custom work -- mainly in fruit and vegetable products. New products are continually being tested.

In USDA we have just finished a taste test of all freeze-dry products now on the market. Results of the test are not published yet, so my discussion of products is based only on my own subjective evaluation. My experience is derived from having tasted all products now on the market, plus a hundred or so others in various stages of development.

Chicken, turkey, and ham appear to have the greatest future among the meats. Several shellfish, as shrimp and crab, have already been market tested and are assured successes. Among the vegetables, asparagus and a few members of the cabbage family, for example broccoli, have potential. Although I am not sure that mushrooms are a vegetable, I do feel sure they will be freeze-dried in large quantities. Among fruits, blueberries, strawberries, raspberries, pineapple, apples, apricots, and others appear economically feasible. I would guess that some products like fish cakes, sausages, stews, soups, puddings, and even whole prepared meals will have a decided market. Specialty foods that appear promising are seasonings, spices, coffee, and fruit powders.

Foods with a high protein or starch content usually freeze-dry easily. Foods high in fat or sugar freeze-dry rather poorly. This is not always true, for I have found avocado dries to an excellent state. When foods have high water content and loose structural characteristics, as for example watermelon, tomatoes, and cucumbers, it is quite easy to freeze-dry them, but virtually impossible to reconstitute them to their original form. If original form were not important, this method would work well, although it probably would be an expensive way of removing water.

## Freeze-Drying Markets

Another way of assessing the potential of the industry is to examine possible markets for the products. These would include:

1. Institutional sales: Freeze-dried foods, such as shellfish, fish, meats, vegetables, are readily adapted to the portion-control method of mass feeding used in restaurants, schools, hospitals, and other away-from-home eating places. To some companies, this sales outlet appears most promising. It's an $18 billion market and growing larger each year.

2. Secondary processing: Freeze-dry ingredients added to soups, preserves, desserts such as gelatin, puddings, ice creams, and bakery products can improve food quality and the natural characteristics of processed foods. As an example, freeze-dried strawberry powder used as a flavoring ingredient in gelatin desserts would materially upgrade the product. Several large food manufacturers are using freeze-dry products in this manner, and at present, this probably constitutes

the largest commercial market for the products. Probably in the future this will be the outlet for a very sizable volume of freeze-dry products.

3. Convenience foods: New freeze-dry products as camp packs, dip mixes, and unique confectioneries have been developed. There are strong indications that this market may be larger than one would expect.

4. Armed Forces: Probably the largest single buyer of freeze-dried products is the Quartermaster Corps. This year, or early in 1963, the Army and Air Force plan on purchasing one-half million pounds of freeze-dry meat, poultry, and seafood. Adoption of other freeze-dried items for the mobilization reserve ration should result in a continuing yearly requirement of 1-3/4 million pounds.

5. Retail: At present, none of these products are available on retail grocery shelves as single items. Here I am not including the secondary processed items mentioned above, nor am I including the camping foods, since they are sold in sporting-goods stores. People in the field agree this market is still several years in the future. It's an extremely tough market to break into with new products, and caution is indicated.

6. Specialty items: It is quite possible that, within this area, freeze-drying may have its greatest impact. As an example, instant coffee dehydrated by this method is said to yield a product with trueness to flavor unequalled by any other drying method. A prominent food company is now installing freeze-dry cabinets in its coffee plant. I anticipate that the freeze-dry product will be used to blend with their air-dried instant coffee. This procedure is expected to make the resulting product more closely resemble home-brewed coffee.

Another group of items within this category are herbs, seasonings, powders, and spices. Techniques have been developed so that such items as parsley, thyme, tarragon, and wintergreen can be dried whole. Items in powder form would include orange and lemon peel, oregano, and members of the onion family. One processor on the West Coast has done considerable basic work in their field, and results look promising. Spice company researchers are scrutinizing products and costs.

## Costs of Freeze-Drying

The future of the freeze-dry industry depends largely on two factors, quality of products and costs of processing. We have discussed quality of the products. Now, what about costs?

We in USDA are currently engaged in an economies of size cost study of the freeze-dry industry. Although our cost data have been collected, they are now being analyzed and are not yet available. In the fall of 1963, we will have a publication on the subject of costs. Nevertheless for now, I will give you opinions of some knowledgeable people currently operating freeze-dry plants. You will find, however, there is considerable difference in their cost estimates.

A custom freeze-dry plant has a rate of 10 cents per pound of raw product. This would be equivalent to 11 to 14 cents per pound of water removed. The manager of this plant feels this charge adequately covers his costs, even though the plant is not yet operating at full capacity.

At a new plant in Canada, it is estimated that costs may be as low as 2 to 3 cents per pound of water removed. Lowness of this estimate is largely attributed to low cost of electric power -- 4-1/2 mills per kw.-hr. However, some quick calculations with our data, using power at one-half cent per kw.-hr., show volume has to be at least 32 tons of water evacuated per day to arrive at the low 3-cent figure.

Mr. Robert Graf of Military Subsistence has this to say about low costs:

"We have heard many estimates of freeze-dry costs, some as low as 2 cents per pound of water removed. We recognize that existing facilities will not ordinarily provide such low production costs, but we regard most currently quoted prices as extremely out-of-proportion to reality."

Dr. John Nair, well-known consultant to the food industry, uses 7 cents per pound of water removed as a rule-of-thumb cost. Others say 7 cents would not even cover the overhead costs at present volume levels. A food technologist employed by one of the large freeze-dry processors puts average costs in the 5 to 7 cents range -- depending on length of drying cycle, original moisture of product, type of heat used, and other factors.

There are many reasons for the present confusion concerning costs. First, the industry is new. Current processing plants are small. Probably the largest freeze-dry plant now in operation has a volume of about one-tenth the volume of an efficient canning or freezing plant. Then, too, the industry is in the experimental stage, and the volume, small though it is, has to carry a large burden of overhead in terms of research and development. Lastly, I suspect that each cost estimate is based upon different input quantities, varying costs per unit of input, and perhaps even quite different plant capacities.

Our cost study, when released next fall, will provide estimates that can take into account much larger volumes of production than are now being used. Economies in cycle time, staggered cabinets to even out the use of power inputs, use of labor, and overhead, appear important considerations related to volume. Other factors we have found important are size of plant, days per year it is used, hours per day, and the products being processed.

Potential of the Industry

In summary, I would say that many products now being freeze-dried are quite acceptable. In general, most people who have tried these products agree that, when considered as dry products, trueness to flavor is maintained to a high degree. They have characteristics associated with other dry products, including ease of storage and handling. In addition, they are more easily rehydrated.

On the minus side, costs are high. Currently, they are much higher than other drying and processing methods, as canning and freezing. Also, our taste-panel results, to be released shortly, show some products to be decidedly poor. There are quite emphatic differences between the same products processed by different companies.

I personally feel the whole drying industry will be expanding and, within this industry, freeze-drying has an important place. Nevertheless, it appears that its major role will be not as a general drying method for a wide range of foods. Rather, the area of use will be as a special drying method for products where it is desirable to retain a very high proportion of the flavor. I do not see wide usage of this process for large volume foods like peas, onions, potatoes, tomatoes, sweet corn, oranges, apples, and so on. All of these freeze-dry satisfactorily. But other drying methods provide products that are almost as good and at considerably lower costs.

If I were to guess the dollar volume of the freeze-drying industry in 1970, I would place the market at somewhere between $1/2 to $1 billion annually. This assumes total food sales will be about $87 billion yearly. In 8 years, this is a potential of about 0.5 to 1 percent of total food sales.

# FREEZE-DRYING EXPECTATIONS

Presented at a meeting of the American Society of Heating, Refrigerating, and Air Conditioning Engineers, Hershey Pa., October 1962 (F-D Report No. 2).

Revised to incorporate suggestions made by H. L. Loeffler, Glacier Packing Corporation, Sanger, Calif.

*Is freeze-drying here to stay?

*Is there an immediate future for freeze-drying?

*What might be the effects of freeze-drying on food processors, warehousemen, wholesalers, retailers, the transportation, container and refrigeration industries?

These are million dollar questions in the food industries today. I don't have complete answers to them, and don't know of anyone who does. However, it is the job of an economist to make estimates, and this is what I'll be doing here. My answers are based largely on results of studies we are currently conducting in the Department of Agriculture.

## Definition of Freeze-Drying

Every person in the field would define freeze-drying a little differently. Here's mine, and it's general rather than technical:

> Freeze drying is a drying method that removes moisture from frozen foods without appreciably changing the form, color or taste of the product. Moisture content of the finished food is reduced to 2 percent or less. After drying, the product is packaged to prevent oxidation and re-entry of water. Bacterial, mold, and enzymatic actions are kept to a minimum in the packaged product through control of oxygen and moisture. Reconstitution is done by adding water or other liquids.

Basically, freeze-drying is changing frozen foods (cooked or uncooked) to dried food by sublimation. This means ice is removed directly from the frozen state to the gaseous state, bypassing the liquid phase. The sublimation process takes place in a vacuum chamber, at low pressure and controlled input of heat. If the process is done correctly, the food is not heated enough to cook or scorch. Theoretically, only distilled water leaves the food, and the resulting product is reported to have a definite advantage over other drying techniques in that oils and other flavor-carrying liquids remain.

Actually, there are flavoring constituents, particularly in fruits and vegetables, that are volatile and are responsible for the aroma and bouquet. These volatile flavors leave the foods in the freeze-drying process, the same as with other dehyration methods. These constituents are the basis of essence recovery in fruit concentration but are not separated or added back in freeze-drying.

In addition to these problems, changes occur in cell structure in the freeze-dried food. There is a migration of salts within the product which has an effect on the subsequent rehydration.

So far, with the development of the industry, it has had good success with products such as shrimp, chicken, and mushrooms.

## Advantages of the Processing Method

Freeze-drying offers several unique advantages. When a product is properly prepared and controlled through freeze-drying, the quality and trueness of flavor of the reconstituted food is said to be comparable to frozen foods. Yet, there is no need for refrigeration in handling, transportation, and storage. The shelf life is long--

generally 2 years at 70 °F. In addition, there is a weight reduction exceeding that of other dried foods. For example 100 pounds of cooked beef reduces in weight to 42 pounds; 100 pounds of mushrooms has a dried weight of 11 pounds.

Some freeze-dried foods have limited shelf life due to highly unsaturated oils which will oxidize in the presence of air and in the absence of water to produce rancid flavors. The development of this rancidity or auto-oxidation is a result of oxygen and of storage temperature. Hence, many freeze-dried foods do not have extended storage or shelf lives, and may have a shorter shelf life than comparable frozen foods. Oxidation of oils also occurs at low temperatures with frozen foods, although considerably reduced. Nitrogen or vacuum-packing of freeze-dried foods appears essential to reduce rancidity in freeze-dried items.

There is one point that has created an interest among peope in the refrigeration industry. Here is a process that uses more refrigeration than frozen foods do in the processing stage (this is true only if mechanical pumps and condensers are used for water evacuation), but eliminates the need of refrigeration throughout the remaining stages of marketing of the product.

People other than refrigeration men are concerned about this possible effect on the refrigeration industry. Here I quote a chainstore man:

> "This is the kind of thing that scares me . . . (he is holding and referring to a package of freeze-dried camper food, now sold only in sporting goods stores) . . . What will it mean to the huge investments we are making today in refrigeration cases and refrigeration transportation equipment? The day will come when we can market this product successfully in food stores. It won't be tomorrow, or a year from now, but it will come. We've got to start considering its implications on the future." 1/

Before getting on with the job of answering the three queries we started with, let's discuss a few findings from our studies which provide a basis for discussion. Here are two leading questions:

How acceptable are freeze-dry products?

What are the costs of processing freeze-dry products?

First, let's talk about how good the products are.

## Quality of Freeze-Dried Foods

We submitted to an experienced taste panel consisting of 5 persons samples of all the freeze-dried products now on the market. 2/ There were 33 different freeze-dry products examined, and in all of the taste tests we compared each freeze-dried product with the same product processed in another way. The standard in most cases was either frozen or canned. Products were tested for general acceptability, and, then, specifically for appearance, flavor, texture, dryness, and tenderness. The results of the tests of flavor are shown in figure 1. Complete results of all taste panel work will be released in a bulletin. 3/

1/ Quoted in Chain Store Age, October 1962, p. 87, from an interview with Mr. Carl Reith, president of Colonial Stores, Inc.

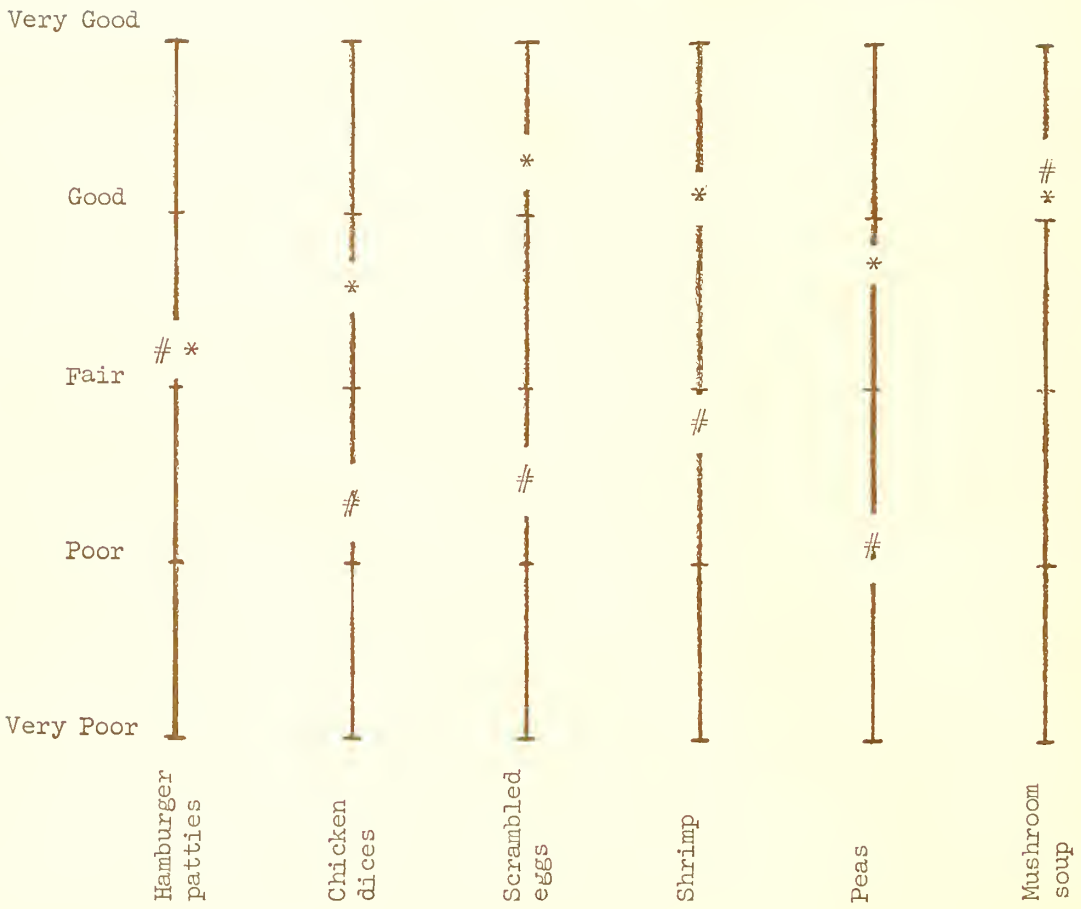
2/ Work in this panel was done by the Human Nutrition Research Division of the Agricultural Research Service, Beltsville, Md., summer of 1962.

3/ Bird, Kermit. Freeze-Dried Foods Palatability Test. U. S. Dept. Agr. Mktg. Res. Rpt. 617. 1963. This publication gives general acceptability, flavor, appearance, texture, dryness, and tenderness ratings for different foods now being sold on the commercial market. No brands are identified and the objective has been to test individual products to assist in assessing the potential of the industry.

## TASTE TESTS

Flavor Ratings of Freeze-Dried Products

PRELIMINARY RESULTS




#=Freeze dried.
*=Comparison standard.

NOTE: Five trained testers tasted each product for three replications.

Figure 1

In figure 1, we show taste panel results for six products: Hamburger, chicken, scrambled eggs, shrimp, peas, and mushroom soup. These were selected to give a cross-section picture of foods now being commercially processed. To get a complete canvas of all freeze-dried foods now on the market it will be necessary to review our publication. All products were cooked before freeze-drying. The tests were conducted after storage of the various items under conditions of commercial usage.

Flavor Ratings

The hamburger had a similar score to the frozen standard. Both were rated "fair." Freeze-dried hamburger is retailed only in sporting goods stores.

Our flavor rating for the freeze-dried chicken is an average of all the several brands now on the market. Flavorwise, chicken was between "poor" and "fair," while the canned product was judged "fair" to "good." Freeze-dried chicken is now being marketed by several firms, although not at retail except in soup mixes.

We could find no processed scrambled eggs being sold, and were forced to use fresh eggs for our comparison standard. Results showed flavor to be much superior in the fresh egg product. The surprising thing to me is that processed scrambled eggs showed up as well as they did under such severe comparison conditions.

Shrimp has been on the institutional market for quite some time. The test illustrated in figure 1 was for shrimp that has no sauce or other flavorings added. It was considered "fair" by the flavor testing and the comparison frozen shrimp rated a "good" score. We also tested shrimp with creole sauce, cream sauce, and salad dressing. The addition of other ingredients to the shrimp raised the score of both the freeze-dried and frozen shrimp to where it was virtually impossible to distinguish them from each other. The same upgrading occurred with other products tested, as chicken with cream sauce and crabmeat with salad dressing.

Frozen peas were judged to have superior flavor to the freeze-dried peas. These peas were not on the market as a separate item, but came from a mix or stew.

Our freeze-dry cream of mushroom soup score is an average of several brands. It was about equal in flavor to the canned mushroom soup comparison product. We found great variability among brands tested.

To make a general statement concerning freeze-dried products, I would say poultry and several red meats have a good potential market. You have seen that cooked hamburger tested well, relative to frozen. Ham also showed up well. Several sea foods, particularly shellfish, have already been market tested, and appear to be assured successes. Among the vegetables I am guessing that asparagus, broccoli, brussel sprouts and several others will have real growth potential. I am not a horticulturalist and am not sure how to classify mushrooms, but I do feel sure the freeze-dry market is a "natural" for them and they will be freeze-dried in large quantities. Among the fruits I would guess that there is a market for many berries, including strawberries, raspberries, and blueberries. Among fruits, peaches, pineapple, plums, apples, and a few others appear promising. These seem to be earmarked for specialized uses in the institutional trade or mixed with other products, as breakfast cereals or bakery mixes. Many products like fish cakes, sausage products, stews, soups, desserts, and even whole prepared meals come to mind as distinct possibilities. Speciality foods such as seasonings, spices, herbs, coffee, and fruit powders are promising items. Some of these are not far off in the future, either. A prominent coffee company is now installing freeze-dry cabinets in its instant coffee plant. Probably the freeze-dried product will be used to mix with the present instant coffee, and the resulting blend is expected to more closely resemble home-brewed coffee.

## A Look at Costs

The future of any industry is largely dependent on its costs. Freeze-drying is no exception. Our cost study is designed so we can look at freeze-dry processing costs from many different angles. In our analysis, we were not concerned with the cost of freezing, packaging, warehousing, shipping, selling, or promotion. Nor did we attempt to include product costs nor the costs of the package itself.

Let's imagine a hypothetical freeze-drying operation. This plant has a capacity of handling 4 tons of water per day. It is operating on a 24-hour day, and has an 8-hour drying cycle. Equipment depreciation is 14 percent. Labor costs are assumed to be about what they would be in a medium-sized midwestern city. The product in the example is cooked chicken dices with 56 percent moisture and is dried to 2 percent moisture.

Figure 2 illustrates freeze-drying costs if this hypothetical plant were operated at varying number of days per year. Here we assume that a full year of operating is 250 working days and 125 days would be equivalent to operating the plant at half-capacity. Costs were 11 cents per pound of water removed for the half-capacity volume. They are 8 cents per pound of water with the plant running at full capacity.

Other conditions yield different costs. For example, our largest model plant under study (not shown) has a capacity of evacuating 32 tons of water per day. Comparable costs to those quoted above were 7 and 4 cents per pound of water. Mushrooms, having a much higher percentage of water (90%) show costs per pound of water considerably less than those quoted for chicken.

## The Future of Freeze-Drying

With results of our studies under our belts we can now hazard some answers to the original three questions. First the question,

"Is freeze-drying here to stay?"

It is! During the past year I have talked with representatives of many major food firms in this country. Most of these were management men. Practically all had an interest in freeze drying; many had investigated the possibilities of freeze-drying, as this technique might apply to their business, and have decided against their company adopting this new technique. However, almost every one of them feels that there is a definite future for this industry. They are testing products, calculating costs, watching developments, and waiting. Others have made a decision to freeze-dry, and many current magazine articles attest to the enthusiasm being shown in the industry.

Now to answer question number two,

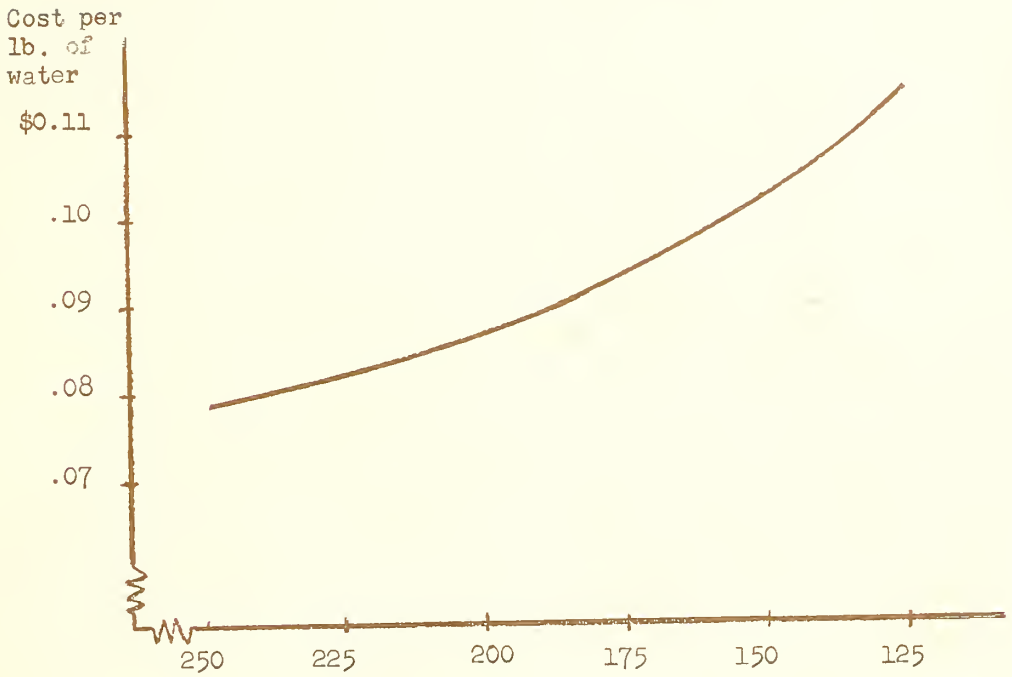
"Is there an immediate future for freeze-drying?"

In our taste testing, some of the products showed up well. Others leave something to be desired. All freeze-dried products are not uniformly good, and we have found significant differences in the same food manufactured by different companies. Flavor loss appears to be a major drawback.

Our cost studies tell us that processing costs are high. However, costs may be lowered. Factors we have found to be especially important are material handling methods, length of the drying cycle, hours a plant operates per day, days per year (as illustrated), moisture of raw product, and capacity of plant. This last one is called "economy of size" by economists,

4/ Bird, Kermit. Freeze-Drying of Foods: Cost Projections. U. S. Dept. Agr. Mktg. Res. Rpt. 639, Dec. 1963. Products analyzed in report include chicken, beef, mushrooms, and shrimp.

Freeze-Dry Processing Costs: Effect of Length of Season on Average Costs per Pound of Water Removed *




This curve is derived from synthetic data. Assumptions are: the product is cooked chicken with a 56-percent moisture. It is dried to 2 percent moisture, by weight, on an 8-hour drying cycle. The plant is on a 24-hour per day operation, and when operated for a full day has a capacity of extracting 4 tons of water per day. There are three labor shifts per day. Labor and utility rates are similar to those we might expect in a medium-sized, midwestern city. Mechanical refrigeration and refrigerated condensers are used in sublimating the water. The freeze-drying equipment is depreciated in 5 years with a 30 percent salvage value at the end of that period. This is a 14 percent depreciation annually. Other equipment is depreciated on a 10-percent schedule.

Figure 2

and is extremely important. Our study shows that in plants of very large volume, costs of certain products become low enough so they could be somewhat competitive with other drying methods. It might be mentioned in this connection that costs of freeze-drying can never be expected to be comparable to those of freezing and canning. This is because in freeze-drying, the product first has to be frozen, and then must be canned. 5/ Thus, a freeze-dried product is frozen, then freeze-dried, and then canned.

However, we must consider other costs besides processing. Some think it possible that transportation, handling, packaging or storing costs may be lowered enough in freeze-dried products that they may offset the higher processing costs involved. 6/

My answer to the question, "Is there an immediate future for freeze-drying?" is yes. The industry is here already. There are some 30 odd products now on the market. Eight companies are in commerical production, and at least three of them are presently enlarging or modernizing their plants. Four plants are being built in this country and two in Canada. Six equipment companies are engaged in designing, building, and installing equipment in this country, and three are active in Europe. There the interest is as great as it is here.

How big will the industry ultimately grow? This is anybody's guess at this time. Two months ago I estimated that by 1970 the industry would have a volume between $1/2 to $1 billion annually. So far I have no reason to lower this estimate. Others are estimating a volume as large as $2 billion annually.

Now to the last question,

> "What will be the effect of freeze-drying on various other industries?"

I don't know. I have no idea to what extend freeze-drying might cut into the frozen food or canning industries. On the basis of our taste tests and cost

5/ Some freeze-dried foods are being packed in laminated foil pouches or envelopes. As yet, this type of package has not reached the sureness of protection afforded by cans.

6/ At the present time, there is not much of a saving in nonprocessing costs for freeze-dried foods compared with frozen foods. Packaging costs are not reduced since the bulk remains the same. Under certain conditions, they may be even higher because of the necessity of using a water-tight, air-tight container. Savings in freight are small, because present rates are largely based on weight, and freeze-drying does not reduce the volume of a product. Carriers may alter their rates to consider both the weight and the volume of the commodity.

For example, a normal freight car holds 1,850 institutional-size cases. Each case holds 30 pounds of frozen peas, or 24 pounds of frozen broccoli, or about 6 pounds of freeze-dried vegetables. Net weight of a car of freeze-dried vegetables is 11,000 pounds. This is 14,800 pounds gross weight. At a rate of $2.42 for a minimum 30,000-pound car, the car charge is $726. This amounts to $6.54 per cwt. of freeze-dried vegetables. The same equivalent amount of frozen vegetables (60,000 pounds gross) has a rate of $1.92 per cwt. plus refrigeration charge of $185, or a total cost of $1,337. The difference of $611 between the car costs is about 1 cent per pound in favor of the freeze-dried foods.

Savings on storage also may be estimated: Volume frozen storage in many areas is 10 to 15 cents per cwt. per month. Storage costs for 6 months may be 0.6 to 0.9 cents per pound. At the present, there are no commercial storage rates for light bulky foods as the freeze-dried ones, but storage savings of 0.5 to 0.7 cents per pound may be considered as maximum.

Combining shipping and storage cost savings, we can expect savings of about 1.5 to 1.7 cents per pound in favor of the freeze-dried foods. This does not do much to offset the extra processing costs of 4 to 11 cents per pound.

studies, however, I would not be overly worried about the immediate future if I were a frozen food processor or a canner. Frozen foods and canned items have cost and taste advantages that will be hard to overcome. There will be particular products, though, in which freeze drying has an advantage.

A frozen food processor should bear in mind that every one of these freeze-dried products was first frozen, and this should remind him that this new processing method could actually provide a market for his frozen foods. We should all bear in mind that procuring the product, preparing it for processing, warehousing, storage, promotion, selling, and distribution are all integral parts of this complex marketing system. These functions are essentially the same for most products and they will not change greatly if freeze-drying does expand. A concluding statement is that undoubtedly freeze-drying will have direct and side effects that will be felt over the whole field of food processing. What these results will be, and their magnitude is difficult to appraise since the industry is new.

## FREEZE-DRIED POULTRY

Published in the "Marketing Newsletter," Oklahoma
Agricultural Extension Service, January 1963
(F-D Report No. 3)

In an era of rapid change it is always a problem to assess which changes are important. This is particularly true at present for people in the food industry. Those failing to adapt to innovation will find themselves left behind, sadder and perhaps even wiser.

A successful business is built upon the ability to foresee changes, to understand how these changes are important, and to be able to take advantage of them. A case in point is the new food processing technique called freeze-drying. Will this be important to the poultry industry? What poultry foods can be sucessfully dried in this manner? How good are they? What are the costs involved? What may be the impact of the new industry upon poultry processors, egg handlers, and poultry producers? Will poultry eating habits change? These questions should be considered when a new food process such as this is introduced.

Before trying to resolve these issues, let's discuss freeze-drying to make sure we understand what is entailed. Freeze-drying is a drying method, not a freezing process. True, the product is frozen, but this is only one step in the drying process. Water is taken out of the food while it is in the solid or frozen state, just as a snowbank will sometimes disappear without melting. The whole operation takes place in a drying chamber in which heat is added to the food while vacuum pumps pull off water vapor. The final product is dried to 2-percent moisture.

Advantages of this method are: (1) If the best known drying techniques are used, most flavor constituents remain in the food; (2) physcial structure stays the same so that rehydration is easy and rapid; (3) the product is storable at room temperature for about 2 years; (4) claims are made that it is shipped more economically than frozen or canned food. Thus, many freeze-dried products combine the advantages of satisfactory palatability, hitherto found only in frozen or canned foods, with the economy in shipping, handling, and storing found in dried foods.

A freeze-dried item needs to be tightly packaged to exclude oxygen, moisture, and light. Currently, most freeze-dried foods are packaged with an inert gas such as

nitrogen. This keeps oxidation to a minimum. Exclusion of oxygen is particulary important, but difficult. The need for a good package is a major problem of the industry today. This problem is accentuated by the fact that many of these foods easily crumble or pulverize.

Before getting on with general statements concerning the way freeze-drying may affect the poultry industry, let's look at research now being conducted by the Economic Research Service, U.S.D.A. Presently we are working on several aspects of freeze-drying, and of particular interest are results of taste tests by our panel of five trained tasters. Each freeze-dried product, tasted at three different sittings, was compared with a standard -- also replicated three times. The comparison standard, not freeze-dried, was similar to each freeze-dried food under investigation. Each product was judged for flavor, appearance, texture, tenderness, and juiciness. 1/ In addition, each was judged for "general acceptability." This latter attribute, general acceptability, is the only one discussed here.

## Preliminary Results of Taste Tests

Poultry tests included chicken dices served plain, in a salad, and creamed. In addition, chicken stew, chicken-rice dinner, chicken noodle soup, and chicken rice soup were also tested, as well as scrambled eggs. Comparison standards for the most part were canned or frozen. All poultry products tested had been cooked during the commercial processing.

Figure 1 shows preliminary results of palatability tests for general acceptability. None of the eight freeze-dried poultry products were rated unacceptable. Diced chicken, served plain, was rated "poor" compared with canned chicken dices that rated between "fair" and "good." When chicken was prepared and tested as a salad, the addition of other ingredients had the effect of raising its rating. This was also true for the canned product. Creamed chicken (made from similar chicken dices) rated between "fair" and "good" for each product being compared.

Chicken stew, freeze-dried, was rated at about midway between "poor" and "fair." The canned comparison product was rated as "good." Freeze-dried and canned chicken noodle soups tested almost the same. This also held true for chicken rice soup. Scores of both soup samples were about midway between "fair" and "good."

Freeze-dried eggs were cooked and scrambled at the processing plant. Compared with the standard, eggs freshly scrambled in our laboratory, they rated "poor." Considering that the standard was made from fresh eggs, the rating is not derogatory.

The general impression of freeze-dried chicken is that by itself it was not as good as the processed standard. However, with the addition of other ingredients -- as in creamed chicken, in soups, and as a salad -- palatability improved. Addition of other ingredients and flavorings simulate usual household cooking conditions and give us a better indication of how these poultry products might be accepted in the market.

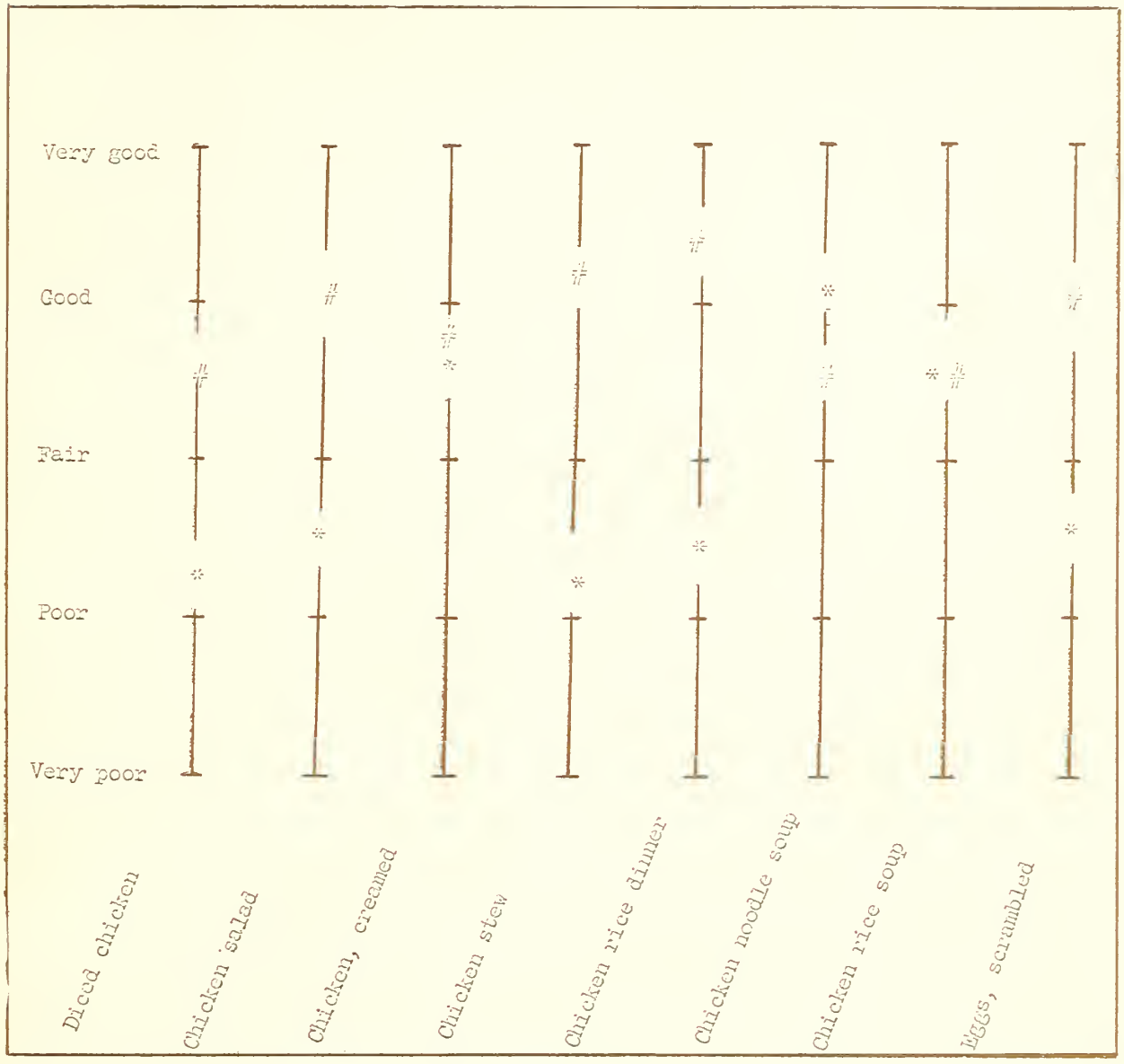
## Costs of Freeze-Drying, Preliminary Estimates 2/

Estimates are being made by many people as to costs of freeze-drying. Many of the apparent differences in these estimates arise from the fact that costs are quite variable and calculation methods

1/ Complete results of the taste study will be released as a research report by the Marketing Economics Division, Economic Research Service, U.S.D.A. Many foods besides poultry products will be included.

2/ Complete cost estimates will be released in a research report of the Marketing Economics Division, Economic Research Service, U.S.D.A. Costs of other products as beef, mushrooms, and shrimp are included.

PALATABILITY TESTS OF FREEZE-DRIED POULTRY FOODS




* - Freeze-dried
\# - Comparison food

5 trained taste testers sampled each of the foods 3 different times. Scores shown are averages of the samplings.

Figure 1

vary. Important factors to consider are: Moisture percentage of the raw product; assumptions regarding length of drying cycle; length of working day; number of working days per year; level of wages being paid; price of such input items as electricity, steam, and nitrogen; and depreciation rate. Hypothetical cost curves are illustrated in figure 2, and our assumptions are listed below the chart.

Our cost curves show the general level of costs for freeze-drying chicken dices, for a hypothetical plant, operated in a specified way. Costs are shown in two ways -- on a "per pound of water removed" basis and on a "per pound of incoming chicken" basis. Costs per pound of water removed are 15 cents when the plant was in operation 100 days per year. The same plant, operated 350 days per year, had costs of 7 cents per pound. Costs per pound of chicken for these same periods of operation were 8 and 4 cents, respectively.

Other assumptions could be made that would radically alter the curves. Costs illustrated are for a small plant (water-removal capacity of 8,000 pounds per day). A plant designed to handle eight times this capacity (64,000 pounds of water per day) and operated 350 days, would have costs of 3.7 cents per pound of water and 2 cents per pound of chicken. Operated at 100 days, this large plant would have costs of 9 and 5 cents, respectively.

The accounting method also affects costs. As an example, depreciation of freeze-dry equipment is a major expense. We have used a 14-percent depreciation rate for equipment. If depreciation rates were lowered, costs would also be reduced.

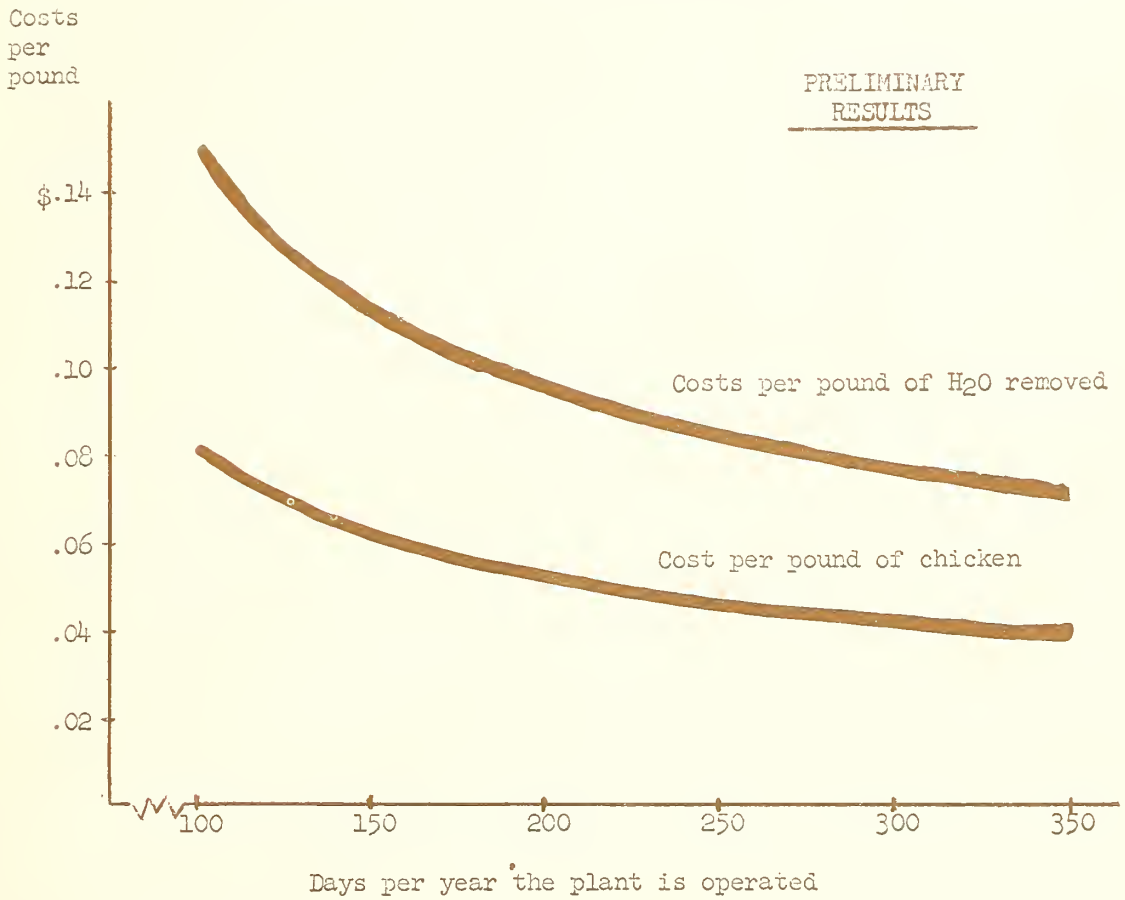
Another way of lowering costs would be to have more drying cycles per day. Our research shows that a 10-hour or an 8-hour cycle lowers costs to a level below the figures quoted.

Currently, freeze-drying costs are high when compared with freezing, canning, or other drying methods. This seriously limits volume potential of this new industry. Nevertheless, this does not minimize the potential for certain products or for special uses of these products. Certainly, freeze-dried eggs or freeze-dried prepared chicken dishes have a market in the camping trade. This market is small, though. Good quality dried poultry products, such as chicken and turkey dices, pieces, and slices, should have a sizable market for use in soups and prepared dishes. At present, no processor is putting plain freeze-dried poultry meat on grocers' shelves, other than in soups, stews, and camper dishes. Whether a retail market might develop within the foreseeable future is uncertain. If it does develop, it could well be a large one.

How will this new processing technique affect our poultry industry? Will consumer eating habits change? Is this new processing method merely a pipe dream, or will it someday be important to a poultry producer, a processor, or an egg handler? Answers to these questions are difficult, since we have so little information we can use for projection purposes. However, there are clues. First, much freeze-dried poultry now on the market is not comparable in quality to frozen, canned, or the fresh product. This would tend to limit its use. On the other hand, when compared with air-dried foods, it is superior.

Secondly, because of high costs, it is hard to imagine freeze-dried foods seriously cutting into the retail market for canned, fresh, or frozen fowl, or for eggs. This would be true for domestic as well as export sales. It is also unlikely that eating habits might be changed, for our present processing marketing methods provide high quality poultry foods at reasonable costs. It is possible, however, that the convenience aspect to the institutional trade might be capitalized upon; and, of course, a big market for these poultry items is the Armed Forces. Recently, the Quartermaster Corps completed its plans for the "Quick Serve" meal which is composed almost entirely of freeze-dried foods. Eggs and chicken

Expected Costs of Freeze-Drying Chicken, Synthetic Data




Product is cooked chicken dices
Incoming moisture 56%
Dried product moisture 2%

Costs involved are only freeze-drying
Costs not considered are freezing, packaging, storing, warehousing.

Assumptions:
Drying cycle - 12 hrs.
Working day - 24 hrs.
Equipment depreciation - 14%/yr.
Electricity rate - $.015/Kw-Hr.
Steam rate - $.80/1000 lbs.
Nitrogen rate - $.008 cu. ft.
Capacity - 8000 lbs. $H_2O$ or 14,815 lbs. chicken/day

Figure 2

are included in the ration.

How large is this market for poultry? No one has the answer to this question. At present five companies produce freeze-dried chicken meat. One produces freeze-dried eggs. All of these companies have a special use for their products -- such as supplying the Quartermaster Corps or other institutional-type buyers. Other uses for the foods are in soup manufacture or in prepared dishes for the camping trade. These companies are large, research-oriented organizations. Their interest indicates that they believe there is now, or will be, a market for freeze-dried poultry. We may expect this market primarily to be in addition to, rather than a substitution, for, present methods of handling poultry. Even though the market is at present a marginal one, we can expect the poultry industry to feel the impact of freeze-drying.

## FORECAST ON A FOOD-PROCESSING METHOD -- FREEZE-DRYING

Reprinted from U. S. Department of Agriculture,
Agricultural Situation, July 1963

*What is freeze-drying?

*What foods can be freeze-dried?

*What are the uses of the food?

*How do freeze-dried foods taste?

*What are the costs of freeze-dry processing?

*How will freeze-drying affect our food industries?

Although complete answers to these questions are not available, research results released by the U. S. Department of Agriculture point to probable answers.

### What Is Freeze-Drying?

Freeze-drying produces a dried food, not a frozen one. Drying is affected by sublimation, which means that moisture is taken out of the food while it is frozen. The ice within the food changes from a solid to a gas, bypassing the liquid phase.

The first step in freeze-drying is to reduce the food particle size. As a result of the smaller size, drying time is shortened and costs are thereby lowered. Next the food is quick-frozen, placed in vacuum cabinets, and heat is applied to the food. The combination of heat and vacuum changes the ice to vapor -- leaving the food in its original size and shape. The food when completely dried has lost 98 percent of its original moisture, and must be tightly packaged to prevent moisture from re-entering. Also, the package must be airtight and light-proof.

To restore these dried foods to a ready-to-eat state, only water need be added, although there is no reason why milk, sirup, lemon-flavored water, or other liquids could not be used.

The method of freeze-drying is not new and has been used in medicine and biology for many years. Blood plasma is a well-known example. Although the technique is not new in these fields, it is new to the food industry. Costs have been high, and still are, but they are now within the range of possibility for many foods.

### What Foods Can be Freeze-Dried?

Foods may be processed either raw or cooked. Chicken and turkey meats appear to have a promising future. Red meats, including beef and pork, shellfish, mushrooms, and some fruits and vegetables also

have potential. In addition, special foods such as coffee, tea, spices, and extracts are possibilities.

In general, any food with a high protein or starch content freeze-dries successfully. Foods that freeze well also freeze-dry satisfactorily. Items high in sugar or fat content are hard to freeze, and thus difficult to freeze-dry.

## Uses of the Foods?

The Army Quartermaster Corps is the largest single buyer of these foods. Our Armed Forces find them particularly suitable for specialized uses because of their long shelf life at room temperature, their light weight, and their true flavor retention. Freeze-dried eggs are a far cry from the spray-dried eggs of World War II. Examples of their application for special purposes are their use by our astronauts and high-altitude mountain climbers.

Some of these foods are being used in the institutional trade. Others are used in mixes such as dried soups and sold at retail. Prepared meals for campers are now being sold.

## How Do They Taste?

Recent taste tests of freeze-dried foods now on the market show that several of these foods are as good or better than their canned or frozen counterparts. Of the items taste tested by USDA, those rating highest were chicken noodle soup, beef noodle soup, and shrimp creole. Others receiving good panel scores were shrimp, crab, beef in several forms, ham, pork chops, and eggs. Many of these foods were tested in mixes and showed their highest scores when mixed with sauces and other ingredients. This was evidenced in chili con carne, stews, creamed dishes, salads, and soups.

## Costs of Freeze-Drying?

Despite recent innovations in drying procedures, freeze-drying is expensive. However, recent research studies by USDA economists show that costs may be reduced in the future as processing plants become larger and more efficient. Although processing costs are now in the range of 7 to 25 cents per pound of water removed, it is quite likely that future costs may settle to a level between 4 and 7 cents per pound. This is still high when compared with freezing, canning, or other commonly used drying methods, but is acceptable, even now, for some of the higher valued or specialized foods. This is particularly true for foods where drying is needed and high flavor retention is essential.

## The Future of Freeze-Drying?

Freeze-drying is expected to gain in popularity as a food-preservation method. At present 12 companies in the United States and Canada are freeze-drying for the commercial market. Abroad, 19 firms produce a variety of foods ranging from coffee to mushrooms. It is unlikely, however, that this new technique will replace our conventional food-preserving methods. Rather, it is expected that freeze-drying will create a group of foods that will meet new needs of the future.

Volume expectations are about $250 million (value at the processing level) by 1970. This is small when compared with our present freezing industry of about 7 billion pounds (meats, vegetables, and fruits only), and our gigantic 19-billion-pound canning industry. However, it does indicate a high rate of growth for this infant industry. We can expect to learn more of its importance as its development unfolds.

# FREEZE-DRIED FOODS AND THE FROZEN FOOD INDUSTRY

Presented at annual meeting of the Maryland Food Lockers Association, College Park, Md., September 1963

Freeze-drying has advanced beyond the realm of the laboratory and test tube. It is now in the evolutionary stage of market testing. For example, a prominent cereal manufacturer is presently conducting market tests of freeze-dried strawberries and corn flakes in Columbus, Ohio. Next month this company will be testing on the West Coast a cereal combination of freeze-dried prunes and bran flakes. In the Midwest, a dairy company is market testing freeze-dried cottage cheese. A dozen or more other companies are testing a range of new foods.

Although not what we would call a full-fledged processing industry, freeze-drying is growing in that direction. In this country, there are about 10 processors drying food by sublimation. In Canada there are several more. In the rest of the world about 23 plants are in production. Several freeze-drying plants are now being built in the United States, and about five are under construction abroad, including one in Japan and one in Brazil. 1/

With this flurry of activity in freeze-drying there is cause for concern among freezers, frozen food distributors, owners of retail stores, locker plant managers, and others in the frozen food business. Conjectures are being made concerning the impact of this process on the frozen food industry, and questions such as these are asked: (1) How do freeze-dried foods compare with frozen ones in palatability? (2) What are the costs of freeze-dry processing? (3) How might freeze-drying affect the frozen food industry?

Is the picture as black as some picture it? Swinburne said, "This I ever held worse than all certitude, to know not what the worst ahead might be." Let's look into what we actually know about freeze-drying and see what the worst might be, in so far as the way the frozen food industry may be affected.

Before we get too deeply involved in looking at the trees, let's look at the forest by first defining the process of freeze-drying, examining its advantages and disadvantages, and discussing some of the products now being dried. Then we can look at markets of these newly-developed foods and then make some reasonable estimates as to how the frozen food of industry may be changed as a result the growth of freeze-drying.

Freeze-drying is the process of removing moisture from a frozen food without melting it. This is called sublimation. It is done in a room, cabinet, or chamber where heat is applied to the food as low pressures remove the water vapor. The food is kept frozen during the process. This sounds simple, and from a theorectical point of view, it's easy to understand. However, it takes a lot of practical know-how to get the right combination of temperatures and pressures to insure a high-quality product. At the culmination of drying, it's a dried product. Moisture in the product at the end of the process is about 2 percent.

Actually, the food goes through some processing even before being dried. Much food now being freeze dried is precooked, although not all. Then it is diced, pulverized, or sliced. Next it is quick-frozen in the usual manner before being placed in the sublimation chamber. When finished drying, the food is removed from the chamber and placed in some kind of moisture and oxygen-proof container such as a can or foil-laminate package. Packag-

1/ For a complete listing of freeze-dried processors and equipment manufacturers see: Bird, Kermit. A Directory of Freeze Drying: Processors, Equipment Firms, and others. U.S. Dept. Agr., Econ. Res. Serv. F-D Rpt. No. 4. Revised October 1963.

ing is one of the major problems of the industry, since a good wrap is essential but expensive.

One advantage of freeze-drying is that the product produced is quite superior to most foods dried by other drying methods, such as sun, spray, roller, or other heat-drying methods. With certain foods this new technique is not greatly superior to other drying methods, but, in general, freeze-dried foods retain their shape better, rehydrate more easily and quickly, and retain color, texture, and nutrients to a higher degree than food from other drying techniques. This food form minimizes shipping, handling, and storing costs, since the water content is so low. The end product is a stable material suitable for room temperature shipping and storage for periods of about 2 years.

A disadvantage of freeze-drying is that, compared with frozen or canned foods, processing costs are high. This is because the food has first to be frozen, then freeze-dried processed, and then canned, or otherwise expensively packaged. Thus, it has the additional sublimation step which is fairly expensive. We'll discuss processing costs later. Then, too, freeze-drying does not produce foods that have quite the quality of frozen foods. Of course, it is the food quality that the consumer uses that counts. Freeze-dried foods may be superior to frozen foods, if the frozen foods happen to have been mistreated during or after processing.

Another limitation of freeze-dried foods is their appearance when dry. To the extent that appearance of a food is associated with moisture in the product, that food appears quite unappetizing while in the dry state. However, these foods are eaten after being rehydrated, so appearance may be only a minor drawback. Fragility is something of a problem, since these foods are friable and crumble easily. A package must be designed to offer protection during shipping and handling.

The major markets for freeze-dried foods are the military, the institutional and the manufacturing ones. To date the Armed Services have been the largest buyer of these foods. They use these foods in regular mess menus and have plans for using them in emergency or combat-type foods. Generally, the institutional market is more progressive than the retail market, in so far as innovations are concerned, and this may be true of freeze-dried foods. I expect the institutional market to use these dried foods in substantial volumes.

In my personal opinion, the manufacturing market is the largest volume market for freeze-dried foods of the future. Here I am thinking of freeze-dried items to be used with other ingredients. An example would be meats or vegetables in soups, stews, or dinners. Or it might be fruits to be used in gelatin desserts, puddings, breakfast cereals, cake mixes, or prepared salads. Another example might be freeze-dried coffee extract to be blended with spray-dried coffee extract, or freeze-dried tea added to other instant teas. Most of these foods will get to the home of the consumer in a disguised form. For example, freeze-dried soups currently manufactured make no mention on the package of the method of processing. Actually, there is little need to mention freeze-drying to consumers, since housewives are not particularly interested in processing techniques, only in suitable products at satisfactory prices.

The retail market for freeze-dried items, sold individually as such, is small and still in the future. Freeze-dried items will have a difficult time penetrating the retail market, since to do so they need something unique to offer in terms of product quality, price, or convenience. Most freeze-dried foods have few of these attributes, except for their storage aspects. They do have novelty, but this provides no incentive for repeat sales. Of the items to enter the retail market in recent months, freeze-dried mushrooms have created the greatest interest. I predict a good future for this food although the package being used appears to contradict all we know about good packaging practices.

In addition to the major markets, there are specialty markets, as for example the camping one. This is small and limited to campers needing the advantages of light weight, nonperishable dried foods combined with the high quality formerly found only in frozen or canned foods. Incidentally, campers using freeze-dried foods must be willing to pay for the convenience they get. Camper-food items are expensive and not suited to people like myself who have found camping an inexpensive way of taking a vacation.

## Quality of Freeze-Dried Foods as Compared with Frozen Foods

In July we released results of our taste tests of freeze-dried foods. 2/ The taste comparisons of freeze-dried foods discussed here are from this study. In the research work of our experienced panel, we compared a freeze-dried food with the same food that had been prepared and handled in the same manner except that it was freeze-dried. For each comparison, we examined a number of palatability characteristics including appearance, flavor, juiciness, texture, tenderness, and general acceptability. In the examples given here we will look at some freeze-dried versus frozen comparisons.

Freeze-dried beef steaks received lower scores for tenderness and juiciness than the frozen beef steaks with which they were compared. In other palatability characteristics the two beef products were similar (fig. 1). Freeze-dried steaks were

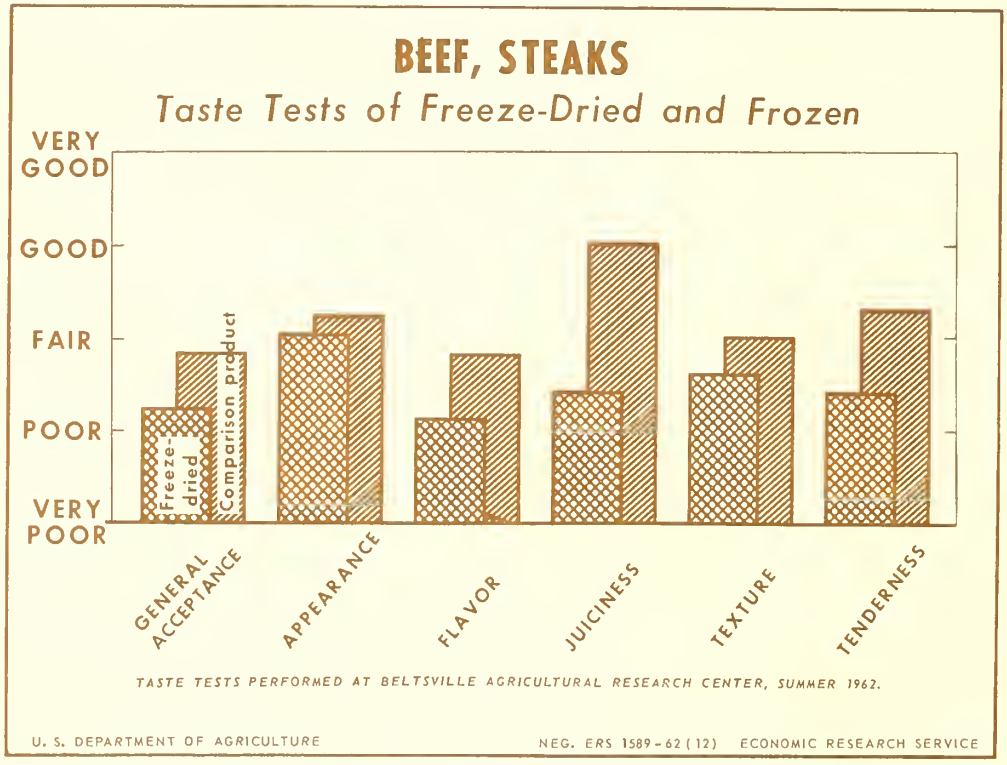



Figure 1

2/ Bird, Kermit. Freeze-Dried Foods: Palatability Tests. U.S. Dept. Agr. Mktg. Res. Rpt. 617. July 1963.

described by panelists as being "watery or mushy" and "dry, yet oozing juice." Authorities in the field tell us that rehydration is a major problem in freeze-drying of meats. 3/

Another product tested was cooked, sliced beef with gravy. We found panel scores were low when this food was compared with frozen, cooked, sliced beef (fig. 2).

In all palatability characteristics, the freeze-dried swiss steak received palatability scores almost indentical to frozen swiss steak. Adverse comments of both the cooked sliced beef and the swiss steak were "stringy," "fibrous," and "dry." (fig. 3).

Among our seafoods tested, six were compared with frozen seafoods. These were plain shrimp, shrimp prepared into a salad in the laboratory, shrimp made into a creamed dish in our laboratory kitchen, and shrimp creole prepared as a mix in the processing plant. Also, there were plain crab meat, and crab meat made into a salad in our laboratory. Shrimp was one of the first freeze-dried foods entered on the institutional market, and since has grown in popularity. Shrimp creole is available only in a camp package.

We found plain freeze-dried shrimp to be about the same palatability level as plain frozen shrimp (fig. 4). The main difference between the two products was in flavor, which may also have adversely affected the "general acceptability" score. In both taste characteristics, freeze-dried shrimp served plain was inferior to the frozen shrimp. In spite of low flavor scores of the freeze-dried shrimp, our panelists made no adverse comments regarding this food.

Preparing shrimp salad from the plain shrimp had the effect of raising both

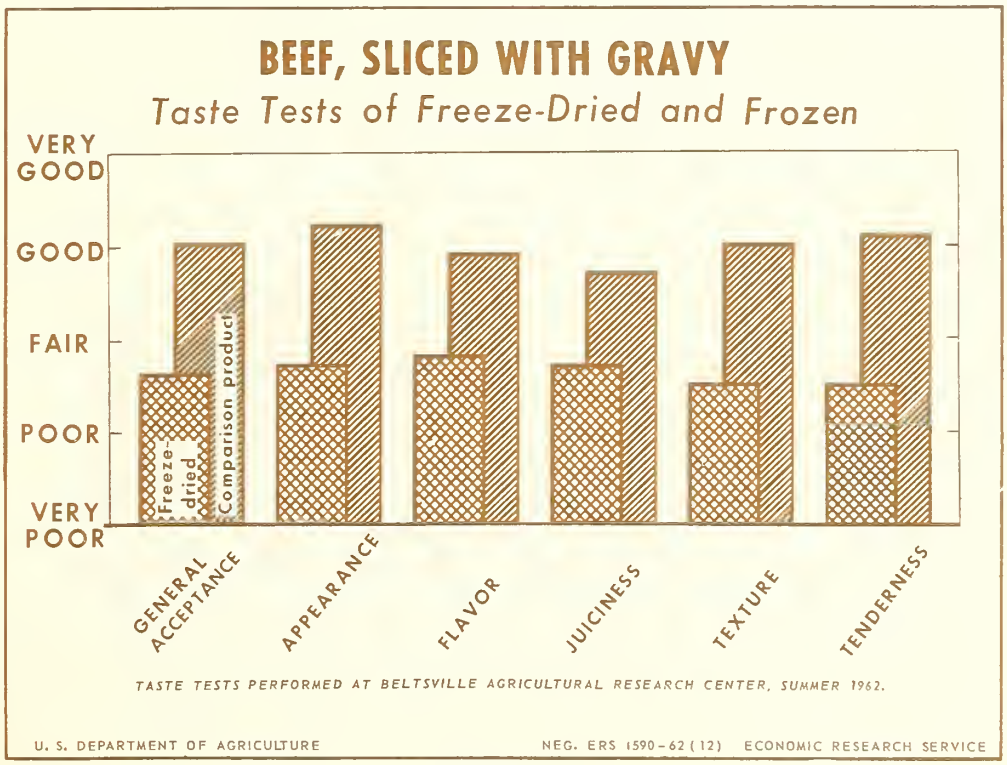



Figure 2

3/ McGuire, John F. Freeze-Drying of Meats: Where It Stands and Where It Is Going. Talk by the F. J. Stokes Company representative at the Sixth Annual Meat Sciences Institute, Rutgers University, Aug. 20, 1963.

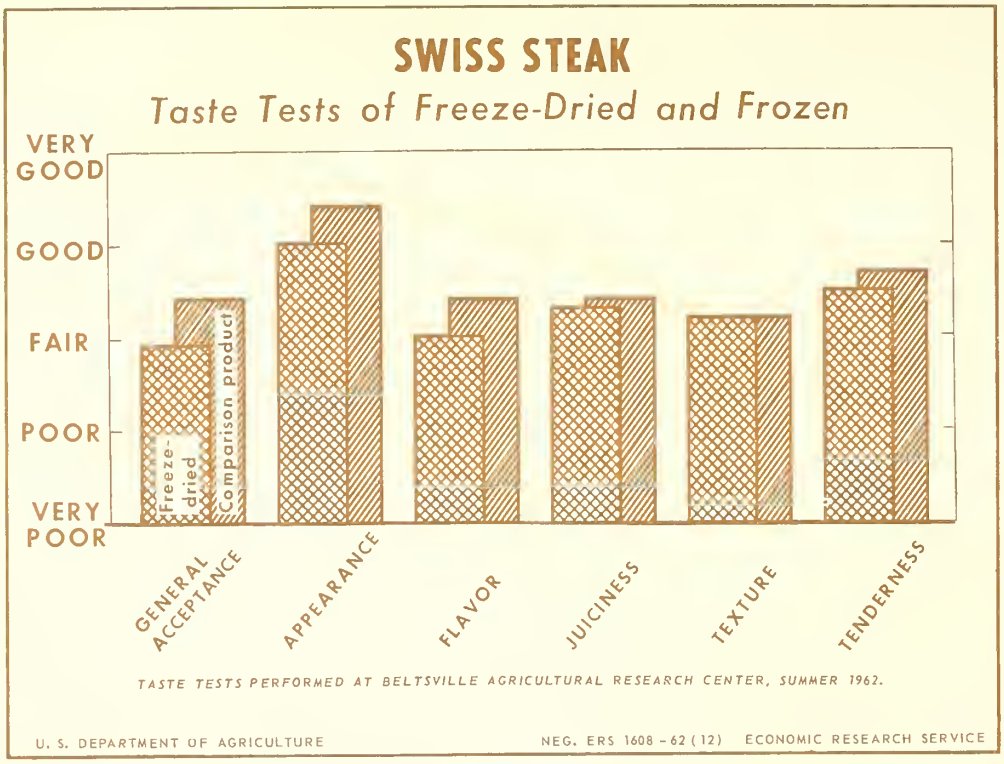



Figure 3

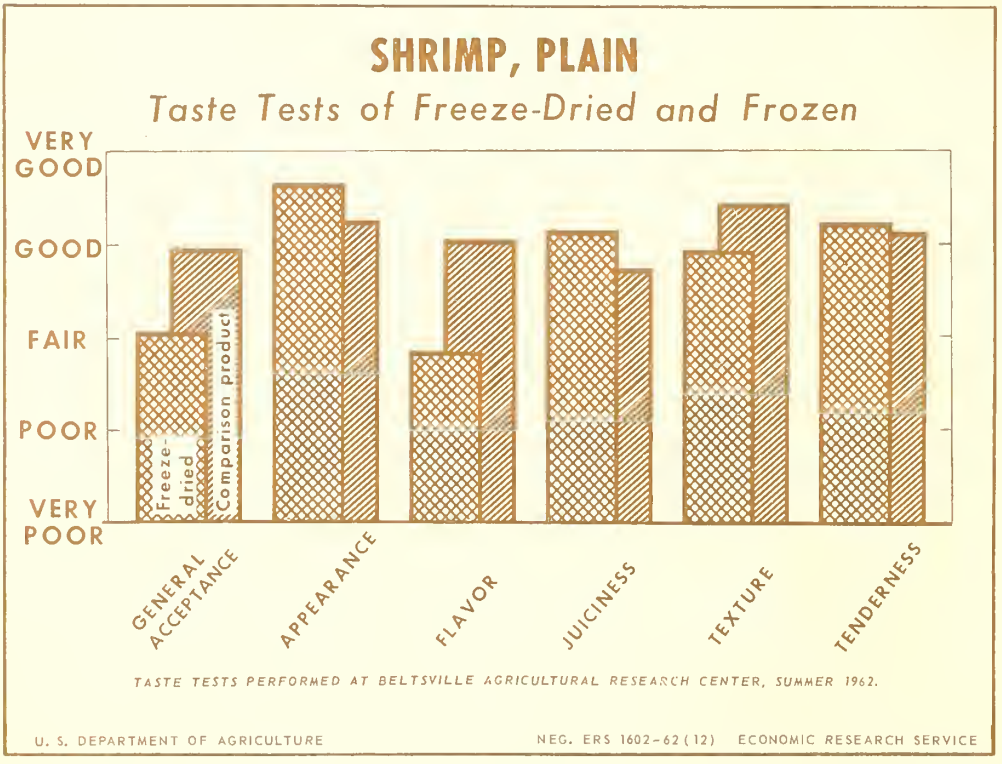



Figure 4

"flavor" and "general acceptability" ratings (fig. 5). We surmise that addition of salad ingredients added flavor that had been lacking in the plain freeze-dried product. Creamed freeze-dried shrimp was the same palatability quality as creamed frozen shrimp (fig. 6). As with the shrimp salad discussed above, flavoring ingredients covered up the flavor absence discernible in the plain freeze-dried shrimp.

Freeze-dried shrimp creole taste scores were equal to or higher than frozen shrimp creole scores (fig. 7). From our research, we concluded freeze-dried creole was superior to the frozen creole tested in all palatability aspects except in flavor and tenderness, where the two products were equal.

Freeze-dried crabmeat was judged by the panelists as being equal in quality to frozen crabmeat (fig. 8). This was true for all palatability characteristics. As with shrimp served plain flavor appeared to be one factor in which freeze-dried crab was weak. As with shrimp, this weakness was evident in the "general acceptability" scoring.

The same crab product that had been served plain was also laboratory-prepared into a crab salad and served to panelists. As with shrimp, "flavor" and "general acceptability" scores improved when crab was part of a prepared dish (fig. 9). All scores of freeze-dried crabmeat salad were high and comparable to scores of the salad prepared from frozen crab.

Freeze-dried peas palatability scores were lower in all aspects that frozen peas (fig. 10). In most flavor characteristics, being between "poor" and "fair." Freeze-dried peas were criticized by panel members as "tough", "having tough skins," and "dry and mealy."

In looking at the whole group of freeze-dried products compared with 10 frozen foods, beef steaks, swiss steaks, creamed shrimp, shrimp creole, crab, and crab salad were acceptable. No food tested was rated as "unacceptable." Freeze dried foods used in prepared mixtures received higher scores than the same foods served plain. On the basis of

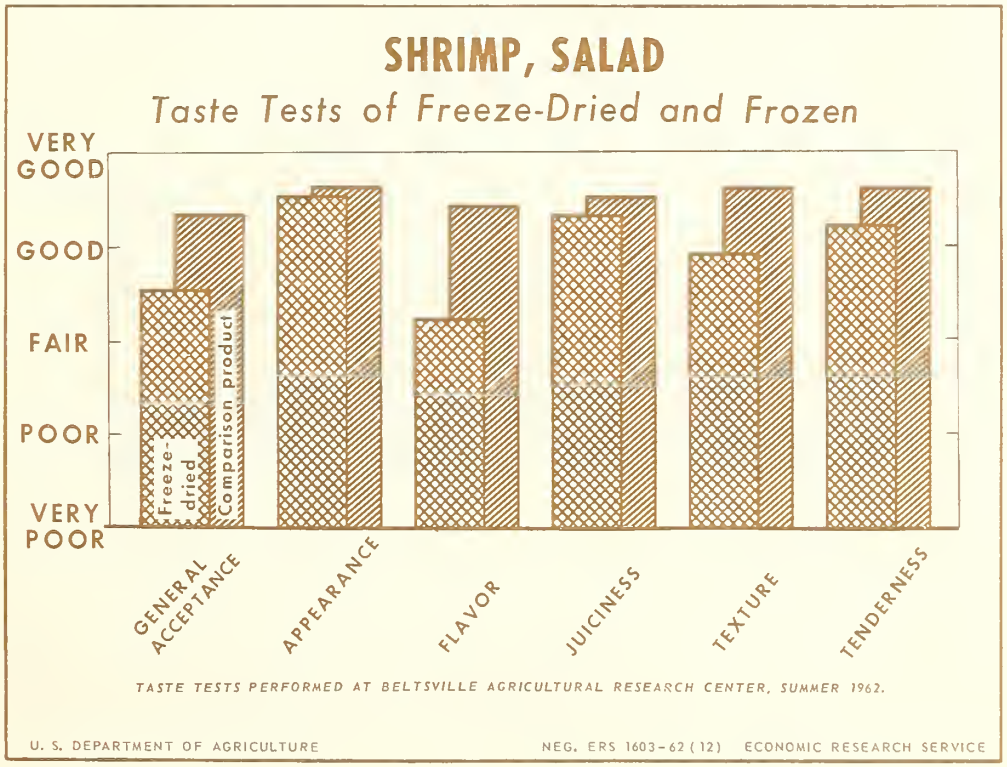



Figure 5

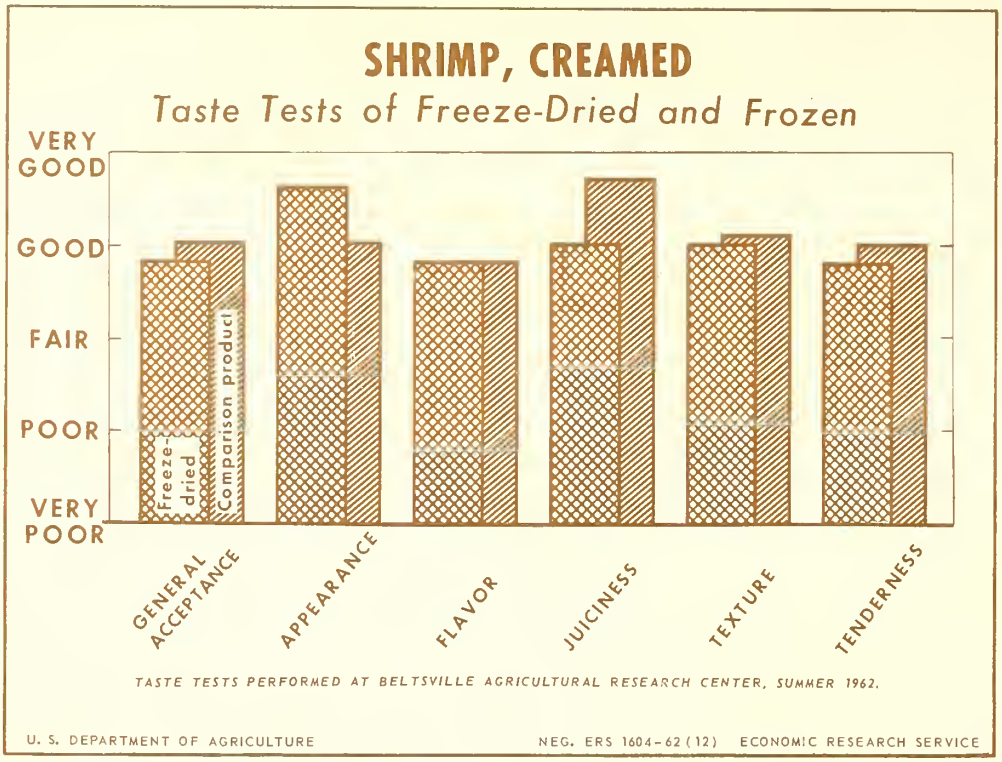



Figure 6

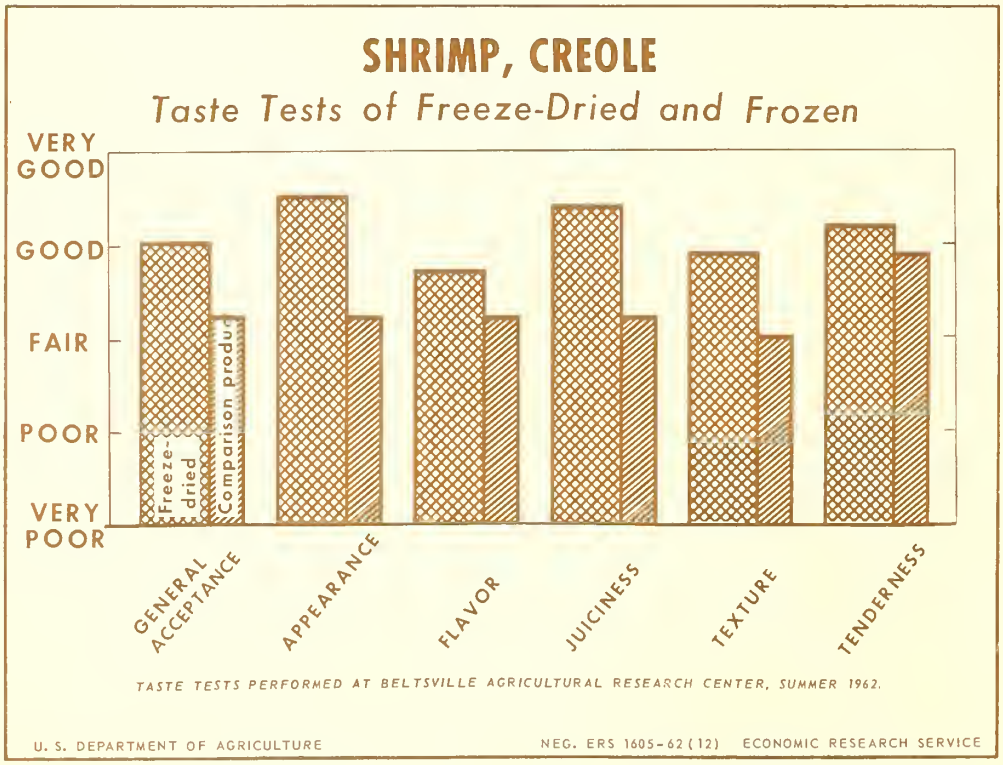



Figure 7

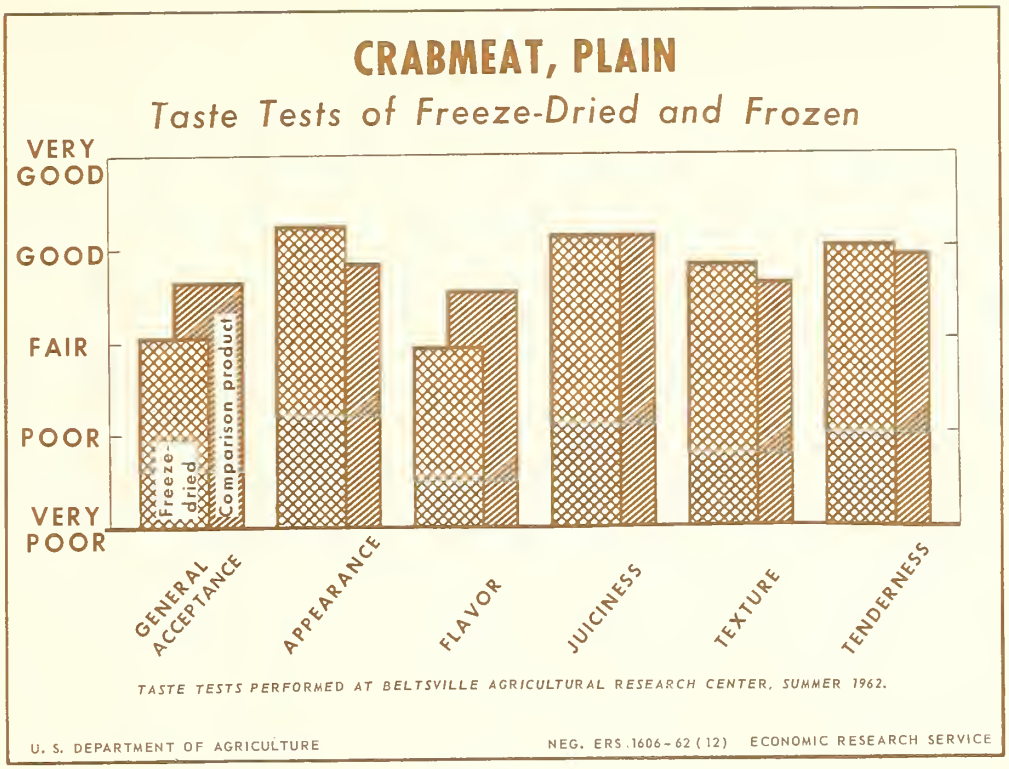



Figure 8

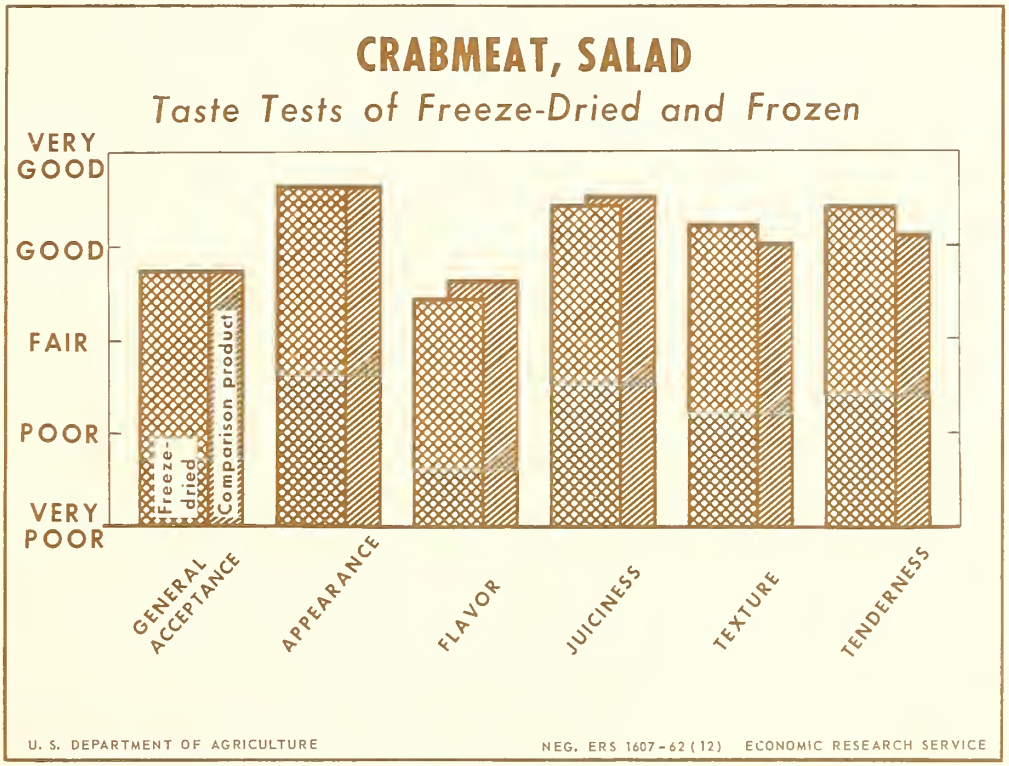



Figure 9

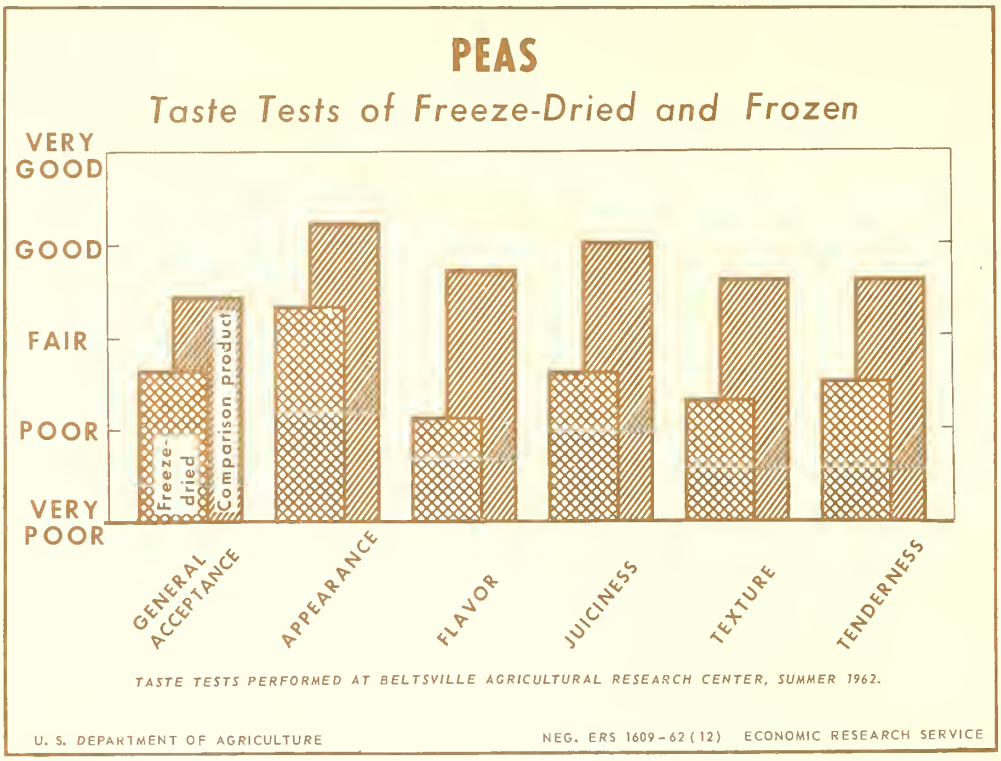



Figure 10

ratings by this experienced panel, freeze dried foods appear to have some prospects for volume production. Their chief market, however, may be in competition with conventionally-dried foods since their lack of palatability seriously limits their competitive aspects relative to frozen foods.

## Costs of Freeze-Dry Processing

Costs of freeze-dry processing depend upon many factors. Of first importance is the size or capacity of the plant doing the drying. The way a plant operates also is important. Length of season, hours per day, length of drying cycle, wage rates, utility rates, moisture of the product to be dried, and assumptions concerning ways costs are handled have been found important. Information concerning freeze-dry costs is derived from work done in USDA during the past year.

Table 1 shows estimates of capacity, investment, and processing costs of a typical freeze-drying plant. Figures within this table do not refer to any particular firm's operation. This plant is hypothetical and has an assumed capacity of evacuating 8,000 pounds of water per day when run 24 hours per day. If this plant were handling cooked beef (60-percent moisture), the frozen product input would be about 13,973 pounds. Dried output of this plant is 5,793 pounds. Shelf capacity of its 5 cabinets is 2,500 square feet. This example plant is approximately the size of several of the larger plants now operating in the United States.

Investment for a plant this size is about $423,000. Most of this is in freeze-drying equipment, $375,000. Annual fixed costs for this plant are about $90,000 which includes 14-percent depreciation on equipment. Also included are building fixed costs, office rent, utilities that do not vary with volume, and salaries of management and clerical staff.

Variable costs for this plant include labor, utilities, and miscellaneous. Table

1 shows a listing of the number of hours for each worker in the plant, wage rate of each worker, and total cost of labor for this plant as operated 24 hours per day. Labor costs are $197 per day. Electricity costs are $53 per day. Steam, which is used both for providing heat for sublimation and in water evacuation with steam jets, is $48 per day. Nitrogen, used for breaking vacuum in the cabinets, is $32 per day. Other utilities, including water and sewerage, are $2 per day. Variable costs total $338 per day.

Processing costs per year for this hypothetical food freeze-drying plant are $158,000. Put on a basis of water evacuated, these costs are 10 cents per pound. Relative to pounds of input product, costs are 5 cents per pound. Costs related to the dried product are 12 cents per pound. In all of these costs, we are assuming that the plant would operate 200 days per year and a 10-hour drying cycle would be used. 4/

Costs may be lowered by operating this same plant on shorter drying cycles. Some plants now in commercial operation are on a 8-hour cycle. Others have longer cycles, with correspondingly higher costs.

Differences among costs for various products being dried depend largely upon their percentage of moisture. Figure 11 shows costs for four products calculated three ways: (1) Per pound of input food; (2) per pound of water evacuated; and (3) per pound of dried food. The chicken illustrated in figure 11 is in dices with 56-percent moisture. The beef has 60-percent moisture. The shrimp has 70-percent moisture and the mushrooms 90-percent. Note the higher percentage of the frozen product, the higher the cost per pound of input product and the lower the cost per pound of water evacuated.

Figure 12 shows the effect of length of processing season on freeze-dried processing costs. In this illustration, chicken is assumed to be the only product and if this plant were operated 50 days per year, costs are 23 cents per pound of water removed. Under the same conditions except that the processing year is 300 days, costs are about 8 cents per pound of water.

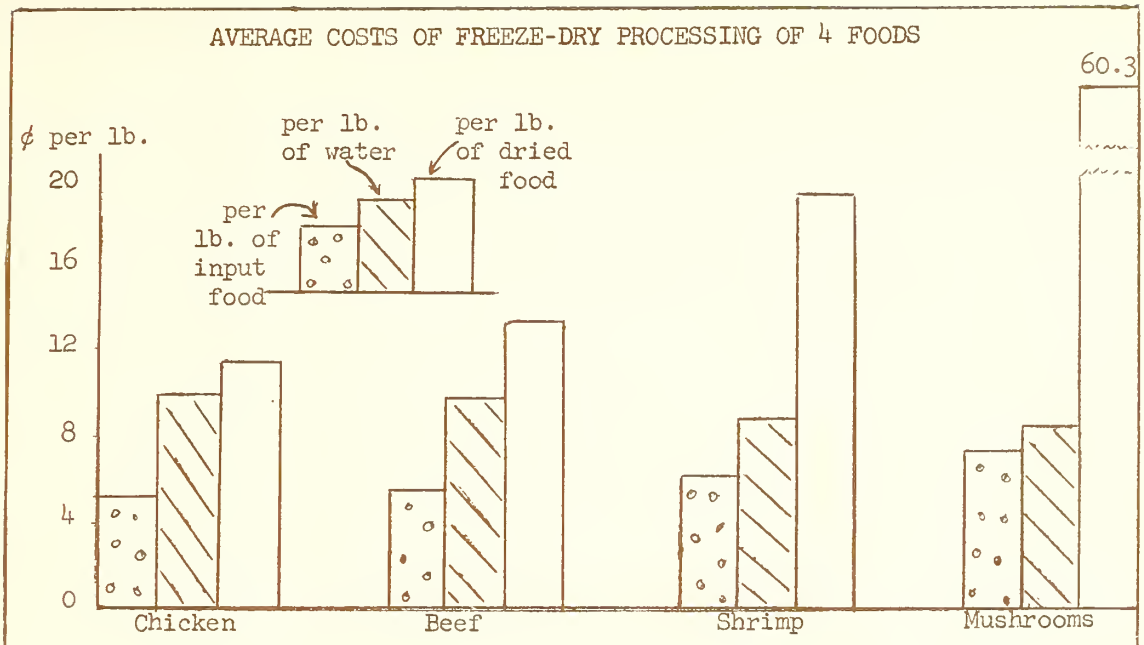
Costs of larger plants have been synthesized in our cost study, and we find plants with a throughput of about 40 to 50 tons of frozen food per day have costs as low as 3 to 5 cents per pound of water removed, if operated at full capacity. Lower costs than these are foreseen as shorter drying cycles and other innovations are used. A flow-dryer, if developed, might reasonably

4/ Because of high costs and relatively small volumes, prices of freeze-dried products are high. As an example, mushrooms sell at about $10 to $12 per pound of dried weight. Peas and corn that have been freeze-dried sell in wholesale channels at $1.50 to $2.25 per pound. Green beans, strawberries, and peaches currently sell at about $4.00 to $6.00 per pound of dried weight. Asparagus, apricots, and cocktail mixes wholesale at $6.00 to $8.00 per pound. Cottage cheese is about $2.50 per pound of dried product. Meats may sell as high as $10 to $12 per pound of dried product. Another important reason for high prices of these foods is the ratio of finished product to incoming product. As an example, let us suppose that 100 pounds of pork chops were to be processed by a freeze-drying plant. The processor trims off all the fat and bone and ends up with 60 pounds of lean meat. This meat is sliced, cooked, and frozen and now weighs 50 pounds. If the frozen cooked lean pork meat is 53-percent moisture, and the end product is to be dried to 2-percent moisture the weight of the dried product is about 25 pounds. This is one-fourth of weight of the input product. If there were no processing costs involved, the equivalent price of the pork, as dried would be 4 times the beginning price. So a 50 cents per pound pork chop is now a $2 per pound item. Add to this the costs of trimming the meat, the cooking, the slicing, the freezing, the drying, and the packaging, and costs rise to levels that are described.

TABLE 1: ESTIMATES OF CAPACITY, INVESTMENT, AND COSTS OF A TYPICAL FREEZE-DRYING PLANT

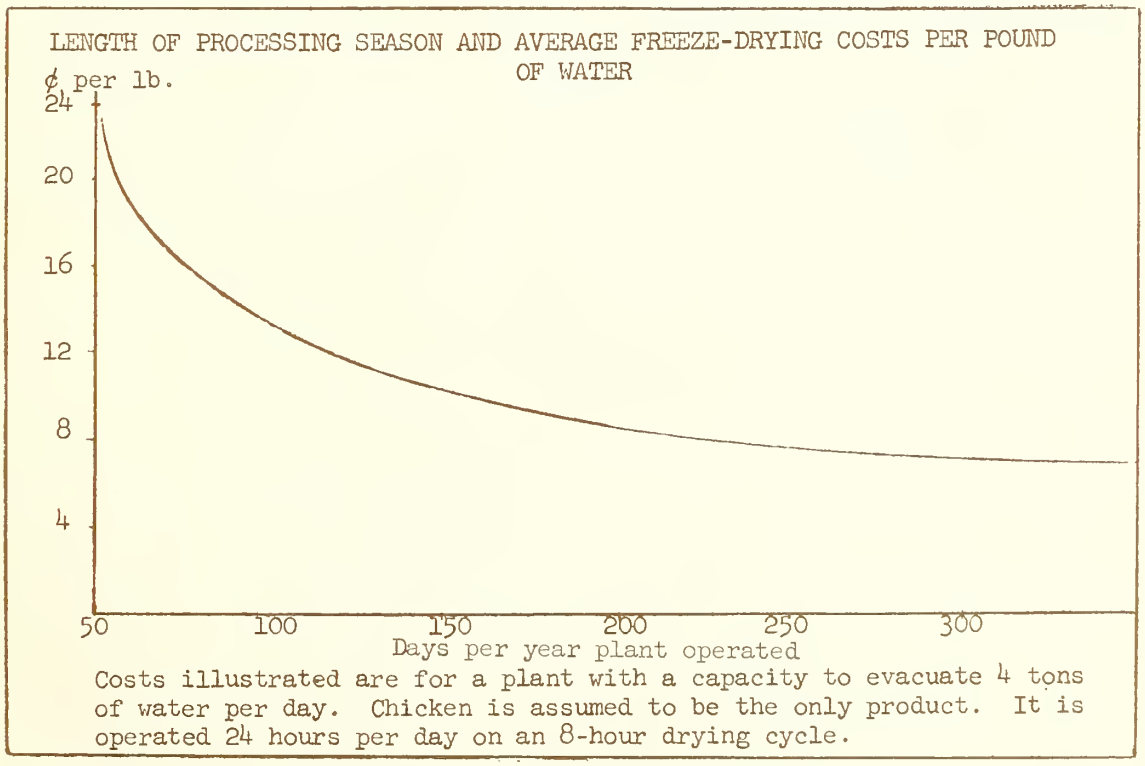
| | |
|---|---|
| Capacity: | |
| Daily volume of frozen cooked beef of 60% moisture (lb.) | 13,793 |
| Daily volume water evacuated (lb.) | 8,000 |
| Daily volume of freeze-dried beef (lb.) | 5,793 |
| Shelf space in drying cabinets (sq. ft.) | 2,500 |
| Capital investment: | Dollars |
| Freeze-drying equipment @ $150 per square feet of shelf area | 375,000 |
| Other equipment | 4,575 |
| Building and land, 2700 square feet of building @ $16 per square foot | 43,200 |
| Total investment | 422,775 |
| Annual fixed costs: | |
| Freeze-drying equipment depreciation @ 14% annually | 52,500 |
| Other costs of freeze-drying equipment | 24,375 |
| Costs of equipment other than drying | 824 |
| Building @ 10.2% | 4,406 |
| Office rent, 120 sq. ft. @ $3.50/year | 420 |
| Fixed utilities | 600 |
| Salaries of manager, secretary, clerk plus their fringe benefits that are paid in cash. | 6,840 |
| Total fixed costs | 89,965 |
| Variable costs per day when plant operated 24 hours per day | |
| Labor: Operator, 24 hours @ $2.06 | 49.44 |
| Assistant operator, 12 hours @ $1.73 | 20.76 |
| Product weighers, 15 hours @ $1.68 | 25.20 |
| Tray men, 8 hours @ $1.68 | 13.44 |
| Tray washers, 8 hours @ $1.68 | 13.44 |
| Department foremen, 6 hours @ $3.96 | 23.76 |
| Maintenance men, 8 hours @ $2.20 | 17.60 |
| Janitor and cleanup 3 @ $1.63 | 4.89 |
| Quality control 2.4 @ $1.77 | 4.25 |
| Total labor, 86.4 hours | 172.78 |
| Labor fringe benefits @ 14% | 24.19 |
| Total costs of labor | 196.97 |
| Utilities (per day): | |
| Electricity, 350 KwHr. @ $.015/KwHr | $ 52.80 |
| Steam, pounds used for heat of sublimation and defrosting 20,000 pounds, used in vacuum pumping 40,000 cost @ $.80 per 100 lbs | 48.00 |
| Nitrogen, 4,000 cu. ft. @ $.008/cu. ft | 32.00 |
| Water and sewerage @ 48,000 gal/day (water for steam jet condensers recirculated through water tower) | .96 |
| Heat, lights, and miscellaneous utilities | 1.00 |
| Total utilities (per day) | 134.76 |
| Miscellaneous variable costs | 6.09 |
| Total variable costs per day | 337.82 |
| Total costs per year | $157,529 |
| Average costs: | |
| Per pound of input product (frozen food) | $ .05 |
| Per pound of water evacuated | .10 |
| Per pound of output product (dried food) | .12 |

Specifications and assumptions: Plant operates 24 hours per day and 200 days per year. Cooked beef is assumed the only product and has 60-percent moisture in frozen state and 2-percent in dried state; 10-hour drying cycles used. Food loaded 2.75 pounds per square foot of shelf area. Wage and utility rates are assumed representative of a small-sized city in the East.




Costs illustrated are examples for a plant with a capacity to evacuate 4 tons of water per day on 12-hour drying cycles. It operates 24 hours per day and 200 days per year.

Figure 11




Costs illustrated are for a plant with a capacity to evacuate 4 tons of water per day. Chicken is assumed to be the only product. It is operated 24 hours per day on an 8-hour drying cycle.

Figure 12

be expected to yield processing costs of 3 cents per pound of water removed.

## Expected Freeze-Drying Volumes

In a new industry such as freeze-drying, it is improbable that volume projections have a high degree of accuracy. With this caution in mind we estimate that about 250 million pounds of food will be freeze-dried in 1970. These pounds are in frozen-weight equivalent. If it takes 1.8 tons of refrigeration to blast-freeze 100 pounds of product per hour, we might expect the refrigeration capacity of the country to increase about 2,250 tons. 5/ This assumes that present freezing capacity is not available for use, and that new freezers would be used 2,000 hours per year.

In addition to freezing food to be freeze-dried, another use for low temperature refrigeration is in the sublimation process. A product with 80-percent moisture requires about 10 tons of refrigeration for each 100 pounds of frozen product to be dried per hour. The plant illustrated in table 1 has a capacity of 333 pounds of water per hour, or 433 pounds of 80-percent moisture frozen input product per hour. This plant would require about 43 tons of refrigeration for use in sublimation. 6/

For purposes of illustration we again assume the freeze-drying industry will process 250 million pounds of frozen product per year and estimate the industry requirements for refrigeration needs. New refrigeration tonnage for freezing and sublimation are 2,250 tons and 10,000 tons, respectively. If we place an investment price of $1,400 per ton of refrigeration, new refrigeration investment of the industry is $17 million (table 2).

## Freeze-Drying and the Frozen Food Industry

Effects of the freeze-drying industry on the frozen food industry may be summarized as follows: (1) For the most part, freeze-dried foods do not have the quality of frozen foods. There are exceptions to this, usually in specific products where the quality of the frozen food is low. Thus, it is not expected that freeze-dried foods will replace frozen foods to any great extent in our marketing system. (2) Cost of freeze-dry processing are now about 8 to 15 cents per pound of water. In the future, they may decline to a range of 4 to 8 cents per pound of water or about 3 to 7 cents per pound of frozen product. Even these costs are high though, relative to costs of freezing alone, and high costs may be an important factor in keeping freezing from achieving volumes now enjoyed by our food canning and freezing industries. For comparison purposes, the present refrigeration tonnage of the food freezing industry in this country may be estimated as follows: In 1961 the volume of farm foods frozen by commercial freezers (excluding seafoods, prepared meals, and frozen dairy products) amounted to 6.7 billion pounds. This is composed of fruits and juices, including concentrates, 1.7 billion; vegetables, 2.3 billion; poultry meats, 2.3 billion; and red meats, 0.4 billion pounds. Frozen fishery items pertain to the 1962 catch and are in terms of millions of pounds: Shrimp 78, other shell fish 9; ocean perch 26; haddock 11, other blocks, fillets, and steaks 19, halibut 43; whiting 34; salmon 15, other round and dressed fish 45; bait and animal food 63. These frozen fish total 343 million pounds. In 1961, canned food processed in the United States (excluding seafoods, prepared mixes, and

5/ About 1.5 tons of refrigeration are needed to plate-freeze 100 pounds of food per hour.

6/ In this country, it is common practice to use mechanical pumps and refrigerated condensers for water evacuation. To my knowledge, there is only one steam-jet plant in operation in the United States. In Europe, however, steam jets are commonly used. They depend upon a plentiful supply of cold water. Although they have a lower investment cost, they have high operating costs. Maintenance costs are high with a mechanical pump system and low with steam jets.

TABLE 2: ANTICIPATED INCREASES IN REFRIGERATION NEEDS CAUSED BY FREEZE-DRYING INDUSTRY IN 1970

| | |
|---|---|
| Expected yearly volume of freeze-dried foods in 1970 (million pounds of frozen food) | 250 |
| Number of freeze-drying plants each with 4 tons per day water evacuation capacity needed to handle above product | 104 |
| Tons of refrigeration needed for freezing foods to be freeze-dried @ 1.8 tons per 100 pounds product dried per hour (2,000 hour year) | 2,250 |
| Tons of refrigeration needed for sublimation of above volume @ 10 tons per 100 pounds product to be dried per hour 1/ | 10,000 |
| Total new tons of refrigeration needed for freezing and sublimation of freeze-dried foods | 12,250 |
| Investment costs of refrigeration per plant using investment cost of $1,400 per ton of refrigeration (Freon system) | $57,120 |
| Investment in refrigeration for the freeze-drying industry (million dollars) | $17 |

1/ In sublimation there are 1,074 BTU's per pound of water as latent heat of condensation. It takes 22 BTU's to subcool from 32° F. to 10° F., and 144 BTU's as latent heat of fusion from water to ice. These total 1,240 BTU's per pound of water sublimated. The plant described above has a water evacuation capacity of 333 pounds per hour, so 1,240 BTU's times 333 pounds of water equals 413,333 BTU's needed per hour. There are 12,000 BTU's per ton of refrigeration, so 34 tons of refrigeration is the theoretical need. A 20-percent loss factor added in makes the refrigeration capacity needed 41 tons. If the product being dried has 80-percent moisture, the flow of frozen input product is 412 pounds per hour (333 ÷ 80 percent). Thus, 10 tons of refrigeration are needed for each 100 pounds of product to be dried per hour.

In calculating industry tonnage needs, we estimate each freeze-drying plant will operate 2,500 hours per year, so the flow of frozen product is 250,000,000 = 1,000 cwt/ hour.

If 10 tons of refrigeration are needed for each 100 pounds of food sublimated per hour, 10,000 tons of refrigeration are needed in sublimation for the industry in 1970.

pet foods) was 19.3 billion pounds as follows: Fruits and juices, including pineapple, 2.8; poultry meats 0.6; and red meats 2.4. In 1962, canned fishery items were 1,097 million pounds as follows: Tuna 344; salmon 182; Eastern sardines 50; Pacific sardines 5; mackeral 54; crab 8; shrimp 14; clam 9; diced clams 15; oysters 4; fish, used as animal food, 374; other 38. These total 7.04 billion pounds of frozen food and 20.4 billion pounds canned food. 7/ Our 250 million pound estimate of freeze-dry production in 1970 is about 4 percent of present frozen food volumes and 1 percent of present canned volumes. (3) Freeze-dried foods

7/ The above figures were obtained from the following sources: Fruit, vegetable, poultry, red meat from various commodity analysis branches of the Economic and Statistical Analysis Division, ERS, USDA. Fishery estimates were made by the Bureau of Commercial Fisheries, U. S. Department of Interior, Washington, D. C.

require refrigeration in both freezing the foods and in the sublimation of them. 8/ Every pound of food to be freeze-dried must be frozen in a conventional manner. 9/ Then, sublimation uses refrigeration. These two uses require about 11.8 tons of refrigeration per 100 pounds of food frozen and dried. (4) If 250 million pounds (frozen equivalent) of freeze-dried foods are processed in 1970, the refrigeration needs of the country will be increased by about 12,250 tons. Assuming this would be additional refrigeration, new investment in refrigeration equipment would be $17 million between now and then.

8/ We may estimate the present refrigeration tonnage of the country being used in food freezing. Volumes of frozen food are now about 7.4 billion pounds. If the plants freezing this food operate 2,000 hours per year, this is a flow of 35,215 cwt per hour. Using our rule of thumb of 1.8 tons of refrigeration for each cwt. of food frozen per hour, there are now 63,387 tons of refrigeration being used to freeze the food output of the frozen food industry. This does not include refrigeration tonnage used in maintaining, transporting, or refreezing of these foods. Nor does it include grocery store food cases, home freezers, locker storage, air conditioners, or other uses for low-temperature equipment.

9/ An exception to this is vacuum freezing. Here the product is placed in a cabinet, frozen by lowering the pressure, and then the usual sublimation process is initiated. This is currently being done in a Canadian plant for mushrooms. It is not true freeze-drying since vacuum freezing process draws out about 20 percent of the moisture and shrinks the food.

Equipment now being designed in France allows for food freezing by conventional means in freeze-dry cabinets. This latter system would be classified as true freeze-drying, even though here, too, the food is frozen in the freeze-dry cabinets.

# IMPLICATIONS OF FREEZE-DRYING FOR COMMODITIES PRODUCED IN THE WESTERN UNITED STATES

Presented at annual meeting of Western Farm Economics Association, Laramie, Wyo., July 1963

Sir Francis Bacon's, "Acorns were good till bread was found," bears some relation to changes presently occurring in our food processing industry. Each day we develop new food items in our food laboratories, and grocery shelves of today show much more variety than a decade ago. Not only may the form, nutrient content, composition, and package be different, but in many instances new processing techniques have been used in preparing the product.

One newfledged processing method receiving attention is freeze-dehydration. Let us look at the possible impact of this industry on our western agricultural economy by asking several questions:

*Which foods are apt to be freeze-dried?

*What are the costs of freeze-dry processing?

*How might this drying technique affect food processors, food handlers, and producers of the West?

## Foods That Freeze-Dry

In our USDA taste panel tests we have observed 33 freeze-dehydrated foods now on the market. Each freeze-dried item was compared with a similar food that had been processed by freezing or canning. The following charts show flavor ratings for several of the foods tested. 1/ Flavor is only one of several palatability characteristics. Others that were tested included texture, tenderness, juiciness, appearance, and general acceptance.

As we glance through these charts we note that most of the foods were rated by the panel as "fair", though some tested "good", and others were "poor." None were rated as "very poor," which would be the equivalent of unacceptable.

Several freeze-dried items tested actually were superior to their counterpart products. Others were about the same quality, but most were somewhat inferior to their comparison standards. Freeze-dried foods rated most favorably where they were in mixtures, as for example, beef stew, chili con carne, soups, and prepared chicken dishes. The inclusion of other ingredients definitely masked a lack of flavor evident in many freeze-dried foods. For example, chicken dices prepared in the testing laboratory as a creamed chicken dish and chicken salad received higher flavor scores than when tasted as plain chicken dices.

In general, foods that freeze easily, freeze-dry satisfactorily. Foods that show greatest promise are meats and some vegetables, although many of our staple vegetables are too low-valued to absorb high processing costs. Many fruits and berries have been freeze-dried experimentally and most of them are fine products. Several of these will have a future. Several dairy foods are being market tested and appear promising. Because of the good flavor retention characteristics of the method, seasonings, spices, and extracts are well adapted to this technique. Other products include seafoods, eggs, coffee, tea, and mixes, such as soups, stews, spaghetti and sauce, curry dishes, and puddings.

1/ For a complete analysis of taste tests see: Bird, Kermit. Freeze-Dried Foods: Palatability Tests. U. S. Dept. Agr. Mktg. Res. Rpt. 617. July 1963.

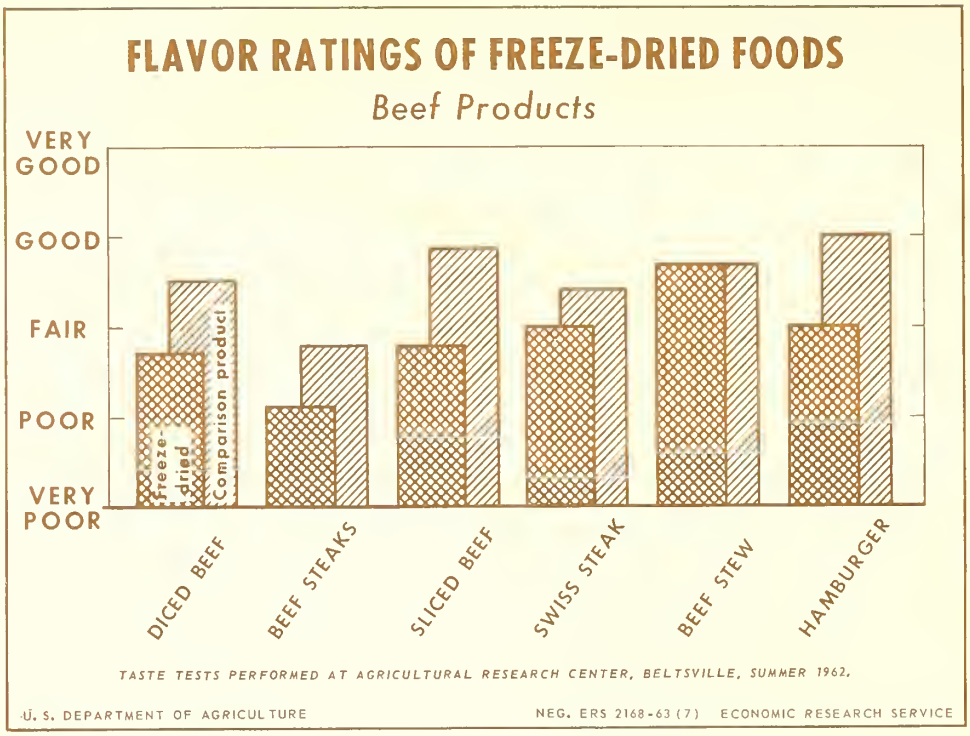



Figure 1

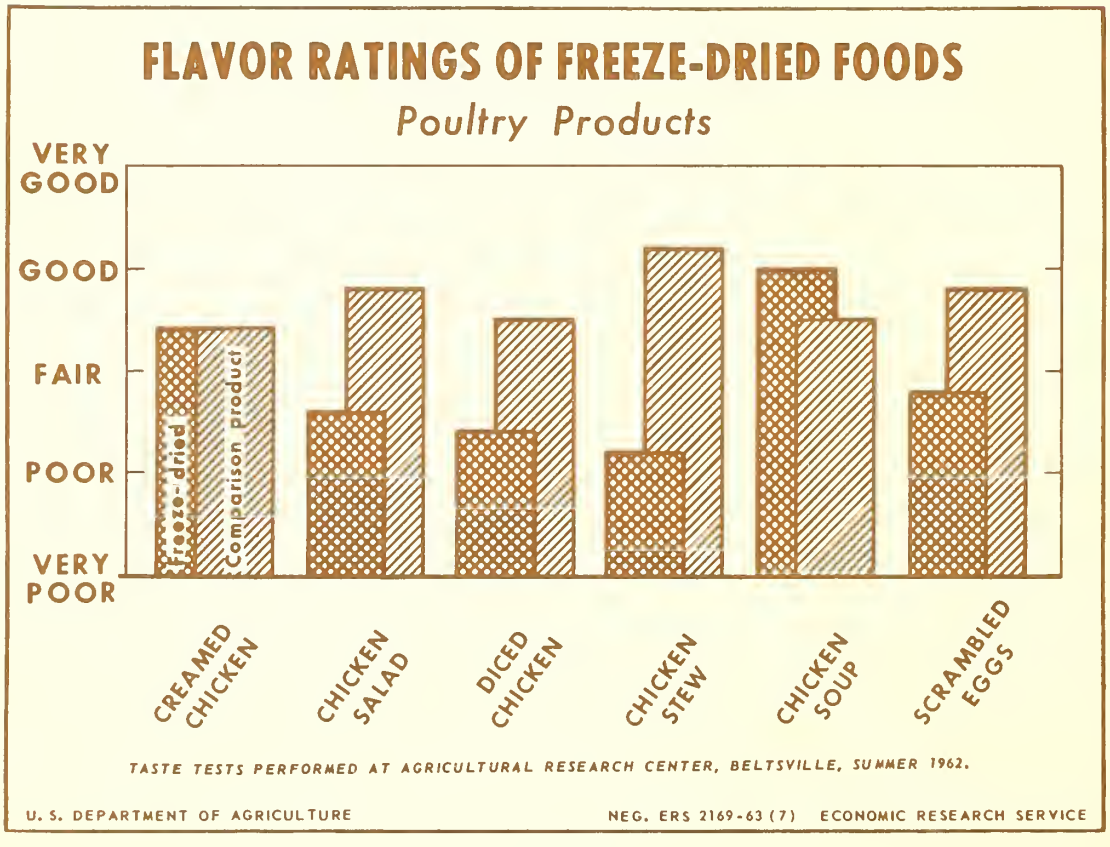



Figure 2

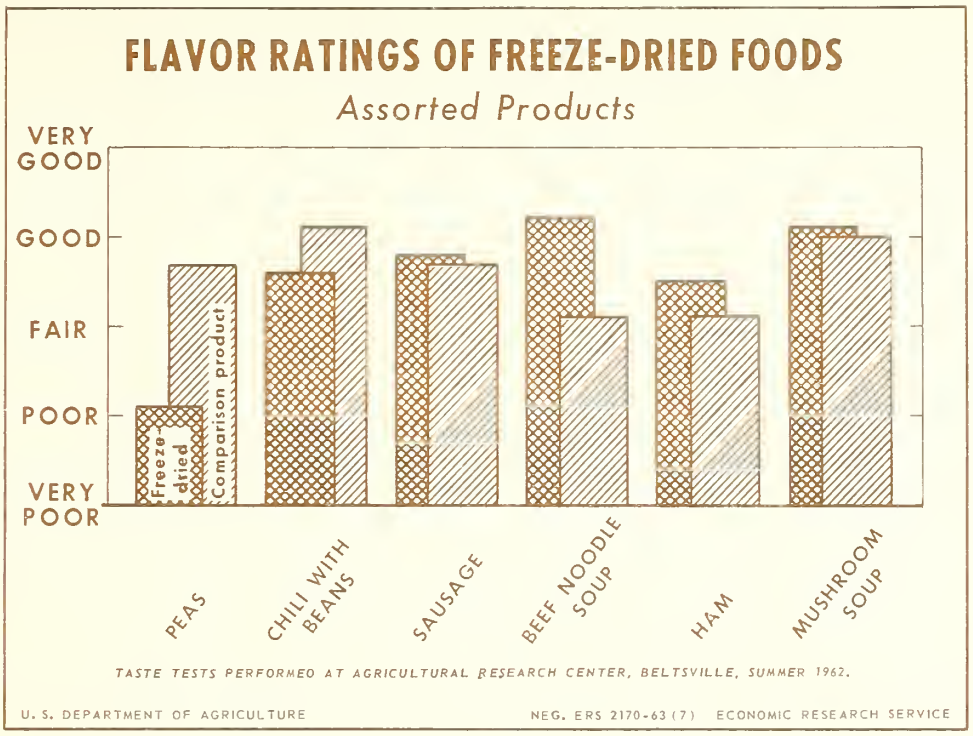



Figure 3

Costs of Freeze-Dry Processing 2/

Costs of freeze-drying depend upon scale of the plant under consideration, volume levels at which the plant is operating, moisture percentages of the product being dried, length of drying cycle (which affects quality of the dried product), and assumptions concerning wages, utility, and depreciation levels. To estimate unit production costs of this infant industry, we used the budget approach to develop synthetic models of four plants. The smallest plant designed (called the 4-ton model) has a water removal capacity of 4 tons per 24-hour day. The other 3 plants are multiples of this one and are designated as the 8-ton, the 16-ton, and the 32-ton. Table 1 reports estimated costs of freeze-drying at these four plants, under certain specified conditions.

Table 1 includes only freeze-dry processing costs. No quick freezing, packaging, promotion, or procurement costs are involved. Investments for the four model plants range from $350,000 for the small 4-ton unit upward to over $2 million for the large 32-ton model plant. In the small plant, there are about 10 full-time (equivalent) employees, and in the largest plant, there are 22 full-time (equivalent) employees.

For the small 4-ton plant, fixed costs approximate $75,000 per year and variable costs $308 per day. Our largest 32-ton model plant has total fixed costs of $422,000 per year and total variable costs of about $900 per day. Because of the large investment in freeze-drying equipment and the high rate of depreciation, fixed costs are about half of

2/ For a complete analysis of freeze-drying costs see: Bird, Kermit. Freeze-Drying of Foods: Cost Projections. U. S. Dept. Agr. Mktg. Res. Rpt. 639. Dec. 1963.

Table 1.--Estimated costs of freeze-drying chicken in plants of varying sizes 1/

| Item | Plant size | | | |
|---|---|---|---|---|
| | 4-ton | 8-ton | 16-ton | 32-ton |
| Capacity: | | | | |
| Daily output (lb.) | 14,815 | 29,630 | 59,259 | 118,518 |
| Water removed daily (tons) | 4 | 8 | 16 | 32 |
| Shelf space (sq. ft.) | 2,000 | 4,000 | 8,000 | 16,000 |
| | Dollars | Dollars | Dollars | Dollars |
| Capital investment: | | | | |
| Freeze-drying equipment | 300,000 | 580,000 | 1,040,000 | 1,840,000 |
| Other equipment | 4,575 | 6,200 | 7,900 | 9,000 |
| Building | 43,200 | 72,900 | 113,893 | 232,694 |
| Total investment | 343,775 | 659,100 | 1,161,793 | 2,081,694 |
| Annual fixed costs: | | | | |
| Freeze-drying equipment | 61,500 | 118,900 | 213,200 | 377,200 |
| Other equipment | 824 | 1,116 | 1,422 | 1,620 |
| Building | 4,406 | 7,436 | 13,657 | 23,735 |
| Office rent | 420 | 504 | 588 | 700 |
| Utilities | 600 | 750 | 900 | 1,000 |
| Salaries and fringe benefits | 6,840 | 9,291 | 12,312 | 18,012 |
| Total fixed costs | 74,590 | 130,997 | 242,079 | 422,267 |
| Variable costs per day: | | | | |
| Wages and fringe benefits | 198.88 | 263.56 | 324.57 | 383.89 |
| Utilities | 102.76 | 173.11 | 283.00 | 477.54 |
| Miscellaneous | 6.09 | 11.72 | 20.96 | 36.98 |
| Total variable costs | 307.73 | 448.39 | 638.53 | 898.41 |
| Total unit costs per pound of removed water | .076 | .063 | .050 | .040 |

1/ Specifications and assumptions: Plant operates 24 hours per day and 250 days per year, using an 8-hour drying cycle. Chicken is assumed to be the only product, has 56 percent moisture incoming, and is dried to 2 percent moisture. Two and a half pounds of product are loaded per square foot of shelf area. Depreciation of equipment is 14 percent. Wage and utility rates are set at levels similar to those in Midwest.

total costs. Thus, a full capacity operation is indicated.

Average costs per pound of water removed are 7.6 cents for the small plant, 6.3 cents for the 8-ton plant, 5 cents for the 16-ton plant and 4 cents for the 32-ton model plant. Clearly, there are economies of scale in this industry. All cost quotations pertain to plants operated at full capacity. Unit costs would be much higher if the same plants operated

less than 24 hours per day or less than a full 250 day year. For example, the 4-ton plant would experience costs of 13 cents per pound if operated only 100 days.

Undoubtedly technological developments, such as a flow-drier, will lower costs -- especially in the larger unit. As a consequence, we may expect future freeze-dry processing cost to be in the range of about 3 to 7 cents per pound. Although these costs are not definite, they do indicate the general level of costs we can expect, and they are useful in making estimates of the future of the industry.

## What Freeze-Drying May Mean to the West

Western United States, with its wide diversification of agricultural commodities, has the following products that may be of future interest to the freeze-drying industry:

1. Beef products of various varieties. Some of these will be cooked, others uncooked. Probably all will be deboned and defatted.

2. Pork cuts, including ham, chops, sausage, and others. As with beef, low value waste portions will be eliminated.

3. Chicken and turkey. These will probably be prepared as dices, slices, or pieces.

4. Shellfish, including shrimp and crab.

5. Mushrooms, most will be for the soup market.

6. Vegetables, including broccoli, asparagus, and several others, but not peas, sweet corn, potatoes, onions, snap beans. Perhaps some tomato products as purees, sauces, and catsup will be dried.

7. Deciduous fruits including apples, peaches, plums, prunes, and cherries. Probably these will be sold as dices, slices, granules, or pieces.

8. Other fruits including citrus, pineapple, dates, figs, avocados, and others. Probably these will be sold as pieces, slices, pastes, or juice concentrates.

9. Berries including blueberries, cranberries, strawberries, raspberries, and boysenberries. Many may be marketed to institutions, bakeries, gelatin-dessert manufacturers, and pudding makers.

10. Dairy products, including cottage cheese, cream cheese, and cheese dips.

11. Seasonings and spices, such as mints, wintergreen, tarragon, thyme, oregano, orange peel, and many others.

In spite of this rather imposing list of western foods that may be freeze-dried, only a few of them will attain large volumes in freeze-dried form. Processing costs still are rather high when compared to those for frozen, canned, or conventionally dried foods. Since costs are considerably higher than for frozen foods, we do not expect a freeze-dried food to replace a frozen one, except in isolated cases. An example of substitution may be by the Armed Forces when a dried food is required, but quality of a higher level than conventional-drying methods produce is desired. Another instance might be in the seasoning or extract field where a high degree of flavor is needed in a dried product. This cost aspect, plus the lack of complete retention of flavor by many items, seriously may limit their volume potential especially for direct sales to consumers via retail grocery stores. However, freeze-dry foods do have outstanding characteristics that should assure them at least a limited market for many products, and possibly a wide market for a few items like mushrooms, shrimp, chicken, and dairy dips.

I do not foresee that freeze-drying will seriously cut into either the freezing or canning industries of the West. Instead I expect it will develop markets that are new, and may account for about 2 percent of the processed food volume by 1970.

# FREEZE-DRYING OF FOODS - A LOOK INTO THE FUTURE

Reprinted from the Marketing and Transportation Situation, August 1963

Freeze-dried food gained national attention recently from its use by high-altitude mountain climbers. It also has been used by our astronauts in space flights. This new processing method offers promise of growing into a multi-million-dollar industry in a few years. Freeze-dried foods may be stored 2 years or longer at room temperatures. Quickly and easily rehydrated, they maintain a high degree of flavor.

This article (1) describes the advantages and limitations of freeze-drying, (2) reports some results of USDA research on taste acceptability of freeze-dried foods and probable costs of processing specified volumes, and (3) on the basis of research, suggests some prospects for commercial development of the process.

## What is Freeze-Drying?

Food to be freeze-dried is first blanched, cooked, or processed in other ways. Then, to facilitate drying, it is cut into small pieces, and they are individually quick-frozen conventionally. The frozen food is placed in a drying cabinet where the pressure is lowered. Heat is applied to the food so the ice sublimates, always maintaining a frozen product. 1/ Water in the form of vapor is removed from the cabinet; when the moisture level in the food has been reduced to about 2 percent, the process is complete.

The final product is a dried, not a frozen food. Thus dehydrated, it may be kept without refrigeration, although it must be tightly packaged to keep out air and moisture. Drying may require 6 to 22 hours, depending on the product and the temperatures and pressures used. However, for most foods an 8 to 12 hour drying cycle is adequate -- providing the food is no more than three-eights of an inch thick and no more than about 3 pounds of food per square foot of cabinet shelf area are dried. This need for small particle sizes in drying may be a disadvantage, since some foods lose their appeal when fragmented. It is theoretically possible, although costly, to dry a large unit of food such as an egg, a roast, or a whole turkey.

This drying technique is not new, having been used many years in biology, medicine, and pharmacy. 2/ The technique is employed in preparing blood plasma and pharmaceuticals, and for drying skin and bone tissue, insects and small animal specimens. The Smithsonian Institution has an exhibit on these techniques applied to museum use. Investigating possibilities of freeze-drying are manufacturers of dairy products who dry cultures and animal breeders interested in semen handling.

Until the last decade, the method was too expensive to use in preserving food. Recent innovations in drying techniques have shortened drying time, however, so many food processors and handlers are interested now. Although costs are still comparatively high, they are within the

1/ Sublimation is the physical change of a solid to a vapor, bypassing the liquid phase.

2/ The newness of its application to foods is shown in a bibliography Freeze-Drying of Foods, A List of Selected References, July 1963, U. S. Dept. Agr. Library List 77. Only 3 books are listed on freeze-drying of foods. However, the bibliography includes titles of over 700 journal, periodical, and magazine articles.

range of possibility for higher-value foods, foods for specialized uses, and dried foods for which good flavor is especially desired.

## Advantages and Limitations of Freeze-Drying

Freeze-dried foods retain many physical characteristics of the frozen foods from which they are derived. Because cellular structure is maintained, the physical state of the rehydrated food is about the same as thawed frozen food. Much original flavor remains since most flavor-carrying oils are not removed in sublimation. Some water-soluble flavors, however, are lost. Flavor loss is a common problem in other food drying techniques, particularly those using heat; and freeze-dried foods generally taste better than other dried foods. In addition, they rehydrate faster than most conventionally dried foods.

Freeze-dried foods have the advantages of all dried foods, except they are more bulky. They are stored and transported without refrigeration, are lightweight, and have long shelf life. These advantages, coupled with flavor retention capacity, give freeze-dehydrated foods an enviable position among processed products.

On the negative side, freeze-drying is slow; and, as a consequence, costs are high. Freeze-drying equipment is expensive; the newness of the industry suggests a high equipment obsolescence, which dictates a fast write-off in depreciation.

Another limitation is that expensive containers are needed. An airtight, moisture-resistant, and light-proof package is needed, and packaging must be done promptly. Entry of oxygen or water into the package shortens the life of the product; hence, a can or tight, laminated-foil pouch is indicated. Many freeze-dried foods are vacuum or nitrogen packed to keep oxygen levels at a minimum. This adds to packaging expense.

## Desirable Foods for Freeze-Drying

In general, foods that freeze well are suitable for freeze-drying. Foods high in sugar or fat content, like fatty pork, do not freeze easily and are difficult to freeze-dry. However, such products as lean pork, avocadoes, and cream cheese are freeze-dried successfully. Foods that lose their physical structure when frozen and thawed make poor freeze-dried foods. Examples are melons, tomatoes, and lettuce. But these may be freeze-dried successfully where retention of physical structure is not important, as in tomato puree.

Freeze-drying seems best adapted to meats, especially poultry and beef. Fishery products, including shellfish, also dry nicely. Most vegetables, fruits, berries, mushrooms, spices, and seasonings are dried successfully. Some dairy products including cottage cheese, dips, cheeses, and beverages seem well adapted.

## Main Uses of Freeze-Dried Foods

The largest purchaser of freeze-dried foods is the U. S. Armed Forces. Many foods suited to special military uses have been developed by Quartermaster personnel. Because of their long shelf life and high quality, freeze-dried foods are now planned as basic ingredients of the new combat rations, the "Quick Serve" and the "Meal Ready to Eat." Both rations include freeze-dried items that were cooked before drying. Some freeze-dried foods, mainly beef, pork chops, and fish squares (uncooked) are being purchased in large quantities for mess usage. Military subsistence this year is taking bids for 210,000 pounds of dried meats. This is equivalent to about a half-million pounds of rehydrated foods.

The institutional market is portion-control and quality conscious. Recent sales of freeze-dried shrimp, crab, and chicken indicate this market may be an important outlet for many of these foods.

The "mix" market promises to absorb large quantities of freeze-dried foods. The entire output of several freeze-dry processing plants consists of chicken dices, beef dices, and mushrooms for dry-soup mixes. These freeze-dry pieces are mixed with other dried ingredients in the soup sold to the public. Other mixes now on the market include chili, creoles, and a mixture of sausage and scrambled eggs. Freeze-dried eggs, by the way, are notably superior to spray-dried eggs used by the military in World War II.

The market for specialized products such as spices, seasonings, extracts, and beverages may well become important. These products retain a very high proportion of their original flavor when freeze-dried. Also included may be dried berries and fruits to be used in bakery foods, ready-to-eat cereals, cake mixes, gelatin desserts, and puddings. At present, one U. S. company is preparing to freeze-dry coffee, and in Brazil another firm is tooling up for coffee-extract dehydration. Several concerns abroad freeze-dry tea.

Another specialized use of freeze-dry items is for the camping trade. Fifteen or 20 prepared dishes are on the market in sporting goods stores. Prices are high. Volume, although small at present, shows signs of increasing.

## Growth of the Industry

A year ago 6 freeze-drying plants were operating in the United States and Canada. Now there are 12, with a combined capacity of about 50 to 60 tons of raw product per day. This comparison typifies growth of this new, but rapidly expanding, industry. In the British Isles there are 5 plants. There are 13 on the Continent. Several in other areas of the world complete the roster of about 32 plants commercially producing foods. 3/ Other plants are under construction, and several now in business are enlarging their facilities.

The largest volumes of freeze-dried items in world production are chicken pieces, meat pieces and slices, mushrooms, and vegetable pieces. 4/ Most are used in dried soups. Other foods include seafoods (especially shellfish), fruits and berries, extracts, and beverages.

Some companies freeze-dry foods for use in products they manufacture and market. Ingredients for soup mixes are an example. Other companies dry and sell freeze-dried items for blending or mixing. Most U. S. firms do contract work for the Government. Two U. S. firms and one in Canada do custom drying. In this operation the customer supplies the product to be dried and may also freeze and package the food. No pattern has emerged as to the type of operation likely to prevail in the future. Several types probably will exist, as is the case in the canning and freezing industries.

## Results of Research

The rapidity of the industry's growth, and even its survival, will depend on its ability to manufacture and sell products that will (1) achieve a stable and relatively extensive volume of production, (2) be cost competitive with canned, dehydrated, and frozen products, and (3) be in a form readily handled by the marketing system. Research results may provide answers to these questions and an economic understanding of whether the future of freeze-drying is promising. Here are some results of USDA research on freeze-drying:

3/ For a complete listing of freeze-dry processors and freeze-dry equipment manufacturers, see: A Directory of Freeze-Drying, April 1963, Kermit Bird, Marketing Economics Division, ERS-USDA.

4/ For poultry industry prospects see: Freeze-Dried Poultry, F-D Report No. 3, January 1963, Kermit Bird, Marketing Economics Division, ERS-USDA, Washington, D.C.

Taste Tests.--During the past year all commercially available freeze-dried foods were tested by an experienced taste panel. 5/ Although results are not conclusive and are not meant to be final evaluations, they give indications of the general level of palatability of freeze-dried foods. Each test food was compared with a similar canned or frozen food.

Freeze-dried items included beef, pork, chicken, seafoods, soups, and mixtures. Palatability of most foods tested was acceptable, according to the panel. Compared with other processed foods, 3 freeze-dried foods were considered superior, 15 were about the same, and 10 were inferior. Freeze-dried foods rated superior were beef noodle soup, chicken noodle soup, and shrimp creole. Those having commendable scores were creamed chicken, ham, sausage, swiss steak, shellfish, and several soups.

Figure 1 shows taste panel results of a representative group of 6 foods. Average panel scores of freeze-dried and conventionally processed foods are compared.

Freeze-dried foods received higher scores when used in prepared mixes than when served plain. Other ingredients and spices in the prepared dishes seemed to offset flavor deficiencies in some freeze-dried foods.

If the ratings of this experienced taste panel are indicative of public acceptance, large-volume production of freeze-dried foods appears feasible. Their chief market, however, may involve competition with conventionally dried foods, which also are similar in usage, lightweight, have long shelf life, and may be stored without refrigeration.

Although freeze-dried foods have some of the quality attributes of frozen foods -- they retain more original physical structure, flavor, and nutritive value than air-, heat-, or vacuum-dried foods -- they are not all-inclusive substitutes for frozen or canned foods. This limits their competitive position in relation to products from these long-established processing industries.

Processing Cost.--Information from a USDA cost study shows that freeze-dry processing may cost from 3 cents to 20 or 30 cents per pound of water removed. In the future, costs may stabilize at about 3 to 7 cents per pound of water removed -- depending on the individual product. 6/

The general purpose of the cost study was to examine costs and analyze factors affecting these costs. These include length of season, hours per day of plant operation, type of product being processed, wage and utility rates, and length of drying cycle. Costs of 4 model plants were developed and organized so effects of these factors could be studied.

Excluding costs of raw materials and packaging, the largest single expense of small freeze-drying plants is labor -- about one-third of total costs. In large plants that are more fully automated, depreciation of equipment is the large expense item -- 40 percent of total costs. Utility costs range from 17 to 20 percent of total costs.

If a small modern plant is operated at full daily capacity for 250 days per year, average costs of freeze-drying chicken are 6 to 7 cents per pound of water removed. In a larger plant under the same conditions, average costs are 4 to 6 cents per pound. These estimates are for plants using 8-hour drying cycles. Where a 12-hour cycle is used, comparable costs range from 4.6 to 8.3 cents per pound of water. Similar costs were calculated for other food products, and they

5/ For complete results see: Bird, Kermit. Freeze-Dried Foods: Palatability Tests. U. S. Dept. Agr. Mktg. Res. Rpt. 617. July 1963.

6/ For a complete analysis of freeze-drying costs see: Bird, Kermit. Freeze-Drying of Foods: Cost Projections. U. S. Dept. Agr. Mktg. Res. Rpt. 639. Dec. 1963.

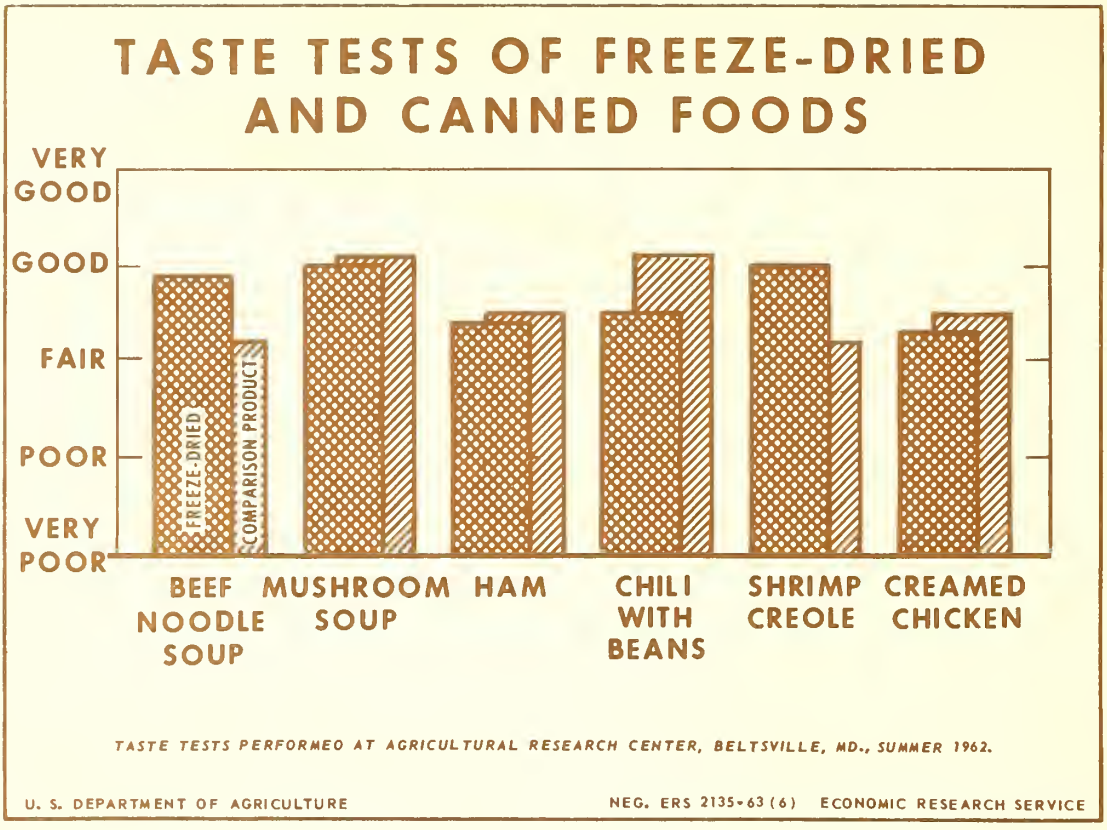



Figure 1

varied in relation to the proportion of water in the raw product to be dried. The accompanying table shows costs for chicken, beef, shrimp, and mushrooms. Note that costs per pound of water removed vary from 6.2 to 7.6 cents per pound (table 1, center column). Costs per pound of input product (the frozen food) are lower, about 4 to 5 cents per pound lower. Thus, freeze-dried chicken will have higher prices than comparable frozen or canned chicken. Costs per pound of freeze-dried food are much higher; as an example, mushroom weights are reduced very much, and cost of the dried product is 45 cents per pound.

Length of season, as in all food processing operations, is an important determinant of freeze-drying costs. For example, if one of the model plants processed shrimp 350 days per year, costs were 3.3 cents per pound. If the plant were operated only 100 days per year, costs were 7.2 cents per pound of water removed.

Hours of daily operation affected costs significantly. A plant operated 24 hours a day had costs of 5 cents per pound of water removed. The same plant operated 16 hours per day had average costs of 7 cents per pound. An 8-hour day operation showed costs averaging 11 cents per pound.

In general, low freeze-dry processing costs may be attained by plants able to handle large volumes of food. A large-capacity plant capable of removing 32 tons of water per day (equivalent to 35 to 40 tons of raw product) will have much lower costs than smaller plants. To keep costs low, plants also need to operate steadily throughout the day and season. In most production areas a large-capacity plant would need to process a variety of foods to obtain its needed volume. To attain minimum cost, a drying plant may need to operate in conjunction with a more complete processing complex that might include food preparation, freezing, storage, packaging, and warehousing.

Table 1.--Estimates of freeze drying costs of 4 freeze-dried foods 1/

| Food to be dried | Cost per pound of-- | | |
|---|---|---|---|
| | Frozen food (input) | Water removed | Dried food (finished product) |
| | Cents | Cents | Cents |
| Chicken, cooked dices, 56 percent moisture | 4.1 | 7.6 | 8.9 |
| Beef, cooked dices, 60 percent moisture | 4.4 | 7.6 | 10.4 |
| Shrimp, cooked and deveined, 70.4 percent moisture | 5.1 | 7.5 | 16.2 |
| Mushrooms, blanched raw, 90 percent moisture | 5.5 | 6.2 | 45.4 |

1/ Costs pertain to plants with a water-removal capacity of 4 tons per day and operating under these conditions: 24 hours per day, 250 days per year, 8-hour drying cycle. Equipment depreciation is 14 percent. Midwest labor and utility rates are assumed.

The Future of Freeze-Drying.--We may summarize results of the taste and cost studies as follows: The market for freeze-dried foods currently is limited to individual items since the process is not applicable to all foods. Foods that appear to have the greatest volume potential are those that may be used in mixes such as soups, stews, prepared meals, and dairy dips. In addition, there are certain seafoods and items used for special purposes that appear promising.

Costs of freeze-drying are high at present, but may be expected to decline to a range of 3 to 7 cents per pound of water removed, depending on volume of operation, wage rates, utility rates, and moisture level of the food processed. Even with costs this low, the potential use of the process is limited to high-value and specialty foods.

This discussion is based on the implicit assumption that present technologies will be continued. It is likely that innovations in processing techniques will lower costs below the expected levels. As an example, our figures are based on a batch process. Newly developed large-volume, flow-process plants are now being engineered, and lower costs may result. Also, as more product testing is done, there is a good prospect that quality of the freeze-dried items will improve.

With these determinations as guides, we may anticipate the future of the industry. First, there does not appear to be an immediate retail market for many of these foods sold as individual items. Sales to the armed forces appear to be the largest market for the products. The second market is for "mixes." The third one is for items used in remanufacturing. The fourth is for specialty items like extracts, seasonings, and spices. The fifth outlet is in freeze-dried coffee, tea, and concentrates. And finally there is the camping market. While small in total, it may be important to individual firms.

Based on test results, we conclude that:

(1) There is a definite future for the freeze-drying industry. This future will be in the products discussed above and products yet to be developed.

(2) The future growth rate of the industry is uncertain. However, if present interest continues, volume

may double or triple each year for the next few years. If so, the volume by 1970 could well be 400 to 500 million pounds of raw input product annually -- about 2 percent of the processed food volume. This is not large, compared with present food freezing and canning industries, which have annual volumes of about 7 billion and 19 billion pounds, respectively. 7/

7/ In 1961, canned food volume (excluding seafoods) totaled 19.3 billion pounds, as follows: Fruits, including pineapple, 4.7 billion; juices, including pineapple, 2.8 billion; vegetables, 8.8 billion; poultry meats, 0.6 billion; and red meats, 2.4 billion. In the same year the volume of frozen food (excluding seafoods) amounted to 6.7 billion pounds, as follows: Fruit and juices, 1.7 billion; vegetables, 2.3 billion; poultry meats, 2.3 billion; and red meats, 0.4 billion.

# A DIRECTORY OF FREEZE-DRYING: FOOD PROCESSORS, EQUIPMENT FIRMS, AND OTHERS

U.S. Econ. Res. Serv. F-D Rpt. 4, Revised Nov. 1963

## Freeze-Dry Processors

United States & Canadian Firms

ARMOUR & CO.
2701 W. Grant
Bellwood, Ill.
Henry Furgol, Pl. Mgr.
(Processes complete lines of meats, some fishery products, eggs, some vegetables, casseroles, and mixes. Many packaged for campers, some such as mushrooms, for retail market.)

CALIF. VEGETABLE CONCENTRATES, INC.
(Subs. of General Foods).
705 Whitmore Ave.
P. O. Box 3659
Modesto, Calif.
G. A. Tessier, Gen. Mgr.
(Processes vegetables, fruits, and meats on a contract basis for institutional use, processing, and QMC.)

CAMPBELL SOUP CO.
Camden 1, New Jersey
Albert Shea, Staff Prod. Mgr.
(Processes chicken, beef, mushrooms, and onions for own brand of dried soups.)

CANADA FREEZE-DRY FOODS, LTD.
P. O. Box 682
579 Speers Road
Oakville, Ontario, Canada
W. R. Smithies, V. P.
224 Merton St.
Toronto, Ontario, Canada
(Processes meats, vegetables, and fruits for remanufacture and convenience foods. Also processes on a custom basis and contract basis for institutional use and field rations.)

ESSEX PACKERS, LTD.
Brant St.
Hamilton, Ontario, Canada
R. R. Furlong
(Not presently operating. Formerly processed meats, stews, and vegetables.)

FREEZ-DRI PRODUCTS CO.
c/o National Ice & Cold Storage
Watsonville, Calif.
S. Castorina, Pres.
P. O. Box 43006, La Tijera Sta.
Los Angeles 43, Calif.
(Processes complete line of freeze-dry foods on a custom basis.)

FREEZE-DRY PRODUCTS, INC.
301 N. W. 8th St.
Evansville, Ind.
Ross Carey, Vice Pres. and Pl. Mgr.
William Fleig, Pres.
(Processes dairy products, meats, and vegetables on a custom basis. Also does contract work for QMC and private companies.)

EDWARD HIRSCHBERG
Burlingame, Calif.
(Custom and contract work for institutional and remanufacturing uses.)

MAXWELL HOUSE DIV. OF GENERAL FOODS
1125 Hudson St.
Hoboken, New Jersey
(Processes instant coffee for use in own blend.)

PAUL A. MARIANI CO.
10930 N. Highway 9
Cupertino, Calif.
Paul Mariani, Jr., Pres.
(Processes fruits, on contract basis, for domestic and export use.)

SLACK BROTHERS, LTD.
Waterloo, Quebec, Canada
Robert Flood, V. P.
(Processes mushrooms.)

THOMAS J. LIPTON, INC.
(Subs. of Unilever)
Albion, New York
Dr. Roy Morse, V. P.
Hoboken, New Jersey
(Processes chicken, meat dices, mushrooms for company's own brand of dried soups.)

UNITED FRUIT & FOOD CORP.
San Carlos, Texas
P. O. Box 187
Edinburg, Texas
Ronald Warnick, Dir. of Manuf.
30 Saint James St.
Boston, Mass.
(Processes shrimp, crab, mushrooms, and chicken for institutional trade. Also complete line of meats for QMC and others on a contract basis.)

WILSON & COMPANY, INC.
Omaha, Nebr.
L. R. Siegel, Manager
Dehydrated Foods Div.
Prudential Plaza
Chicago 1, Ill.
(Manufactures complete line of ground and diced meats, poultry, shrimp, and some prepared dishes. Marketed under own name. Also processes for QMC and others on a contract and custom basis.)

Firms Located Abroad

AERATED FOODS, LTD.
41 Saint Mary Ave.
London, E. C. 3
G.E.C. Dier, Dir.
Walton Works: 149
Heisham Road
Walton-on-Thames
Surry, England
(Freeze-dried tea marketed through retail stores and vending machines.)

AFICO (Maggi G.m.b.H., sub.)
Singen, W. Germany
(Processes meat pieces and vegetables for dried soups.)

BLA BAND PRODUKTER AB and AB VATO (Unilever Associates)
Stalverksgatan, Postbox 240
Halmstad, Sweden
Gunnar Holmen, Prod. Mgr.
(Processes chicken, meats, and vegetables which are sold at retail in form of soups and complete dinners.)

BROOKE BOND, & CO., LTD.
35 & 37 Cannon St.
London E. C. 4, England
(Processes tea.)

DAHLHOFF & KING (N.Z.), LTD.
Invercargill, New Zealand
J. N. Dahlhoff
G. P. O. 3040
Wellington, New Zealand
(Processes meat products.)

FRUTAS SOLUVEIS FRUSOL S.A.
Jeremias Lundarelli Neto, Dir. Supt.
Campinas
Est. Sao Paulo, Brazil
(Plant under construction and will be in production in late 1963, drying sliced bananas for baby food, instant coffee.)

H. HARTOGS' FABRIEKEN, N.V.
(A Unilever affiliate)
Oss, Netherlands
(Processes chicken and mushrooms for soup mixes, and vegetables.)

ERIN FOODS
(Of Irish Sugar Co., Ltd.)
Mallow, Ireland
J. Ginnell, Dir. of Food Processing
7 Clare Street
Dublin, Ireland
(Processes meats, vegetables, fruits, and seafoods.)

JAPAN JIFFY FOODS, INC.
(Subs. of Ajinomoto Co.)
Takeo Mizote, Exec. Dir.
Kondo Bldg.
163 Umegae-Cho, Kitaku
Osaka, Japan
(Processes meats, shrimp, mushrooms, eggs, fruits, soybeans, curd, and mixes for retail institutions, and export. Does contract defense work.)

J. LYONS, LTD.
London W. 14, England

Also Cadby Hall
London W. 2, England
(Processes fruits, vegetables, and dairy products.)

KNORR FOOD PRODUCTS
(Subs. of Corn Products, Inc. of Argo, Ill. P. O. Box 345c)
Leutschenbach, Strasse 46
Zurich 11, Switzerland
(Processes meats and vegetables for own soups mixes sold in Europe.)

LIEBIGS EXTRACT OF MEAT CO., LTD.
Sligo, Ireland
(Processes scampis, fish, and vegetables for institutional and retail trade.)

LUCAS AARDENBURG, N. V. (A Unilever affiliate)
Hoogeveen, Netherlands
(Processes vegetables.)

MOLKEREIGENOSSENSCHAFTEN eGMBH
3148 Dahlenberg, Germany
Mr. Kautz, Gen. Mgr.
(Processes cottage cheese, milk and associated dairy products -- expected date of opening October 1963.)

NESTLE' (Maggi)
Case Postale 13
Vevey, Switzerland
(Processes meat pieces and vegetables for dried soup mixes.)

N.V. PRESERVENBEDRIJF-BREDA
P. O. Box 207
Manager, D. d'Arnoud Gerkens
Breda, Netherlands
(Processes vegetables, poultry, beef, and veal.)

ROYAL HOLLANDIA MILK & FOOD CO.
(Subs. of Nestle' Maggi)
Vlaardingen, Netherlands
(Processes complete range of foods.)

S A C A F
(owned by Spert Products, Inc. of NYC, NY)
Salerno, Italy
Dr. Aliero Poggioli, Tech. Dir.
(Continuous process freeze-drier installed, but not in commercial operation Oct. 1963.)

SITPA
(Maggi affiliate)
Auxonne, France
(Processes freeze-dried meat and vegetables for soup mixes.)

TECHNOPROMIMPORT
Moscow, U.S.S.R.
(No detailed information.)

UNILEVER, N.V.
Unilever House
P. O. Box 760
Rotterdam, Netherlands
(Processes chicken for dried soups and other uses in Oss, Hoogeveen, and Halmstad.)

## Freeze-Dry Equipment Manufacturers

United States & Canadian Firms

AMERICAN INSTRUMENT CO.
8030 Georgia Ave.
Silver Spring, Maryland
Jerry Scott, Sales Mgr.
(Design and manufacture laboratory and pharmaceutical sublimators and accessories.)

AMERICAN STERILIZER CO.
2424 W. 23rd Street
Erie, Pa.
James J. Wingenbach, Sales Mgr.
(Design and manufacture complete line of sublimators.)

BETHLEHEM FOUNDRY & MACHINE CO.
225 W. 2nd St.
Bethlehem, Pa.
William L. Root, 3rd , Manager of Vacuum Freeze-Dry Div.
(Design, manufacture, and install complete line of sublimators.)

CHEMET ENGINEERS, INC.
2560 E. Foothills Blvd.
Pasadena, Calif.
C. N. Sjorgren, Pres.
(Design, manufacture, and install complete line of food sublimators, plus associated food handling facilities.)

DEL-VAC ENGINEERING
461 N. Eucalyptus Ave.
P. O. Box 722
Inglewood, Calif.
John E. Blaine, Jr., Pres.
(Design, manufacture, and install sublimators.)

DRESSER VACUUM DIV. of Dresser Industries
P. O. Box 111, 150 "A" St.
Needham Heights, Mass.
H. A. Herzig, V. P.
(Design, manufacture, and install Leybold equipment in North America. Specializes in continuous flow equipment.)

EDWARDS HIGH VACUUM, INC.
3279 Grand Island Blvd.
Grand Island, N. Y.
(Represent Edwards High Vacuum, Ltd. in U. S.)

F. J. STOKES CORP.
5500 Tabor Road
Philadelphia 20, Pa.
John Maguire, Manager of Food Equipment Processing Div.
(Design, manufacture, and install complete line of sublimators and associated equipment.)

FMC CORP.
Box 1120
333 W. Julian St.
San Jose 8, Calif.
Ben L. Manfree, Appl. Eng.
Central Engineering Laboratory
P. O. Box 580
Santa Clara, Calif.
(Design, manufacture, and install complete line of sublimators.)

FREEZ-DRINAMICS SYSTEMS, INC.
6920 Melrose
Los Angeles 38, Calif.
William R. Ulrich, Pres.
(Design, manufacture, and install custom built sublimators. These available for sale or lease.)

FREEZE-DRY PRODUCTS, LTD.
224 Merton St.
Toronto 7, Ontario, Canada
J. E. Margison, Pres.
(Design, manufacture, and install custom sublimators for food, biological, and pharmaceutical uses.)

HULL CORPORATION
Hatboro, Pa.
Lewis Hull, Pres.
J. H. Leary, Sales Mgr.
(Design, manufacture, and install complete line of sublimators.)

J. P. DEVINE MANUFACTURING CO.
49th Street & A.V.R.R.
Pittsburgh, Pa.
G. R. Cox, Pres.
(Design, manufacture, and install custom sublimators. Special units to purchaser specification.)

NRC EQUIPMENT CORP.
160 Charlemont St.
Newton 61, Mass.
Orvis M. Knarr, Sales Manager
(Manufactures accessory equipment.)

REPP INDUSTRIES
Route 208
Gardiner, New York
T. N. Thompson, Adm. Ass't.
(Design and manufacture pharmacuetical and laboratory sublimators.)

THERMOVAC INDUSTRIES CORP.
41 Decker St.
Copiague, N. Y.
Kenneth Rivlin, Ex. V. P.
(Design, manufacture, and install sublimators.)

VACUDYNE CORP.
375 E. Joe Orr Road
Chicago Heights, Ill.
Fred Lindstrom, V. P.
(Design, manufacture, and install complete line of sublimators.)

VIRTIS CO., INC.
Gardiner, New York
(Design and manufacture laboratory sublimators.)

Firms Located Abroad

A/S ATLAS
Baldersgade 3
Copenhagen, Denmark
O. Begtrup-Hansen
(Design, manufacture, and install complete line of sublimators.)

C O G E R, S. p.A., MACCHINE E. METALLI
4, Via Santa Marghreita
Milano, Italy
Giuseppi G. Pasque, Pres.
(Design, manufacture, and install vacuum equipment.)

EDWARDS HIGH VACUUM, LTD.
Manor Royal, Crawley
Sussex, England
T.W.G. Rowe, Head, Res. Div.
(Design, manufacture, and install sublimators for biological preparations and food. Also manufactures high vacuum pumps and compressors, gauges, switches, and other accessories.)

EDWARDS ALTO VUOTO S.p.A.
(Owned by Edwards High Vacuum Ltd.)
Via Gallarate N 217
Milan, Italy
P. M. della Porta, Dir.
(Design, manufacture, and install pilot plant and custom-built sublimators.)

JAPAN VACUUM ENGINEERING CO., LTD.
Nippon Seimei Ginza Bld.
5, 1-Chome, Cinza-Nichi, Chuo-Kù
Tokyo, Japan
Factories at Yokohama and Amagasaki
(Design, manufacture, and install own sublimators. Also handle Vickers-Armstrong equipment.)

LEYBOLD-ELLIOTT, LTD.
Tunnel Ave.
London S.E. 10, England
J. M. Dalgleish, Head, Freeze-Drying Dept.
(Design, manufacture, install, and commission Leybold sublimators within Sterling area of Commonwealth.)

LEYBOLD-HOCHVAKUUM-ANLAGEN GMBH
Gaedestrasse
Koln-Bayental (Cologne)
Postfach 195
Germany
G. W. Oetjen, Dir.
(Design, manufacture, and install complete line of sublimators.) Represented in U. S. by Dresser Vacuum Division.

MITCHELL ENGINEERING LTD.
Tavistock House, North
Tavistock Square
London, W.C.1, England
E. A. Woodward and P. B. Mason
Also Peterborough, Lincolnshire, England
(General engineering. Design, manufacture, and install sublimators for coffee extract and portable use.)

S.O.G.E.V. (Subs. of Thomson-Houston Co. of New York)
50 Voie Du Four
Choisy-Le-Roi, France
(Design, manufacture, install, complete line of sublimators and other vacuum equipment.)

VICKERS-ARMSTRONG
P. O. Box 8, So. Marston Works
Swindon, Wiltshire, England
E. E. H. Lefever, Prod. Mgr.
R. T. Cox, Sales Coordinator
(Design, manufacture, and install complete line of sublimators.)

(Company associated with Dr. Eliano Cannetta, firm name unknown.)
Via Della Rosa
Poagnasco di Sergrat,
Midland, Italy
(Manufactures cabinets.)

Miscellaneous Freeze-Drying Firms Including Handlers of Freeze-Dried Foods, Processors of Nonfood Items, Manufacturers of Controls and Others.

ATLAS D. BRAZIL
Industria e Comercio S/A
Caixa Postal 7984
Sao Paulo, Brazil
(Handles A/S Atlas equipment in South America.)

BERNARD FOOD INDUSTRIES, INC.
1208 E. San Antonio St.
San Jose, Calif.
Frank S. Bernard, Manager
(Owns no sublimators. Purchases freeze-dried food from other processors and sells under own brand to campers.)

BUFLOVAK EQUIPMENT DIV. OF BLAW-KNOX
1543 Fillmore Ave.
P. O. Box 2041
Buffalo 11, New York

CORP. PICKER INTER-AMERICANA
White Plains, New York
G. C. Oswald
(Distributor of RePP and Virtis laboratory sublimators outside of United States and Canada.)

COURTLAND LABORATORIES
5555 Valley Blvd.
Los Angeles 32, Calif.
Paul Bogikes, V. P.
(Pharmaceutical freeze-drying.)

EVANS RESEARCH & DEV. CORP.
250 E. 43rd St.
New York 17, New York
Dr. Wm. E. Holland, V. P.
(Product development, process evaluation, taste and consumer panel studies.)

FISHER SCIENTIFIC CO.
203 Fisher Building
Pittsburgh, Pa.
(Manufactures controls for sublimators.)

FOOD DEVELOPMENT UNIT of UNILEVER LIMITED
Greyhope Road
Aberdeen, Scotland
(Processes meats, poultry, vegetables, and fruits--for experiments and own use.)

THE FOXBORO CO.
924 Neponset Ave.
Foxboro, Mass.
Wendell S. Young, Engineer
(Design and manufacture controls for freeze-dryers.)

FREEZE-DRIED FOODS DIV. of KORODY MARINE CORP.
12822 Simms Ave.
Hawthorne, Calif.
Paul Korody, Pres.; Terrance Miller, Tech. Dir.
(Plant under construction and expected to be in production in Februrary 1964 in mushrooms, herbs, vegetables, and chicken.)

FRIGID-DRY CORP. OF AMERICA
3201 W. Hampton
Milwaukee, Wis.
(Custom freeze-drying research, custom commercial production, and custom equipment.)

FRITZSCHE ENTERPRISES
4601 Downers Drive
Downers Grove, Ill.
Herbert W. Fritzsche, Pres.
(Consulting and development.)

HOLLAND DAIRY CO.
Holland, Ind.
(Distributes cottage cheese and other dairy products.)

KRAFT FOODS DIV. OF NATIONAL DAIRY PRODUCTS CORP.
99 Park Ave.
New York 16, New York
Fred Huneke, Head of Institutional Products
(Distributes United Fruit and Food freeze-dried foods.)

M & R DIETETIC FOODS
625 Cleveland Ave.
Columbus 16, Ohio
(Freeze-dried mothers' milk.)

MOTTO
Address unknown, Italy

(Distributes through own chain of Italian bakeries and coffee houses of 100% freeze-dried coffee.)

JOHN NAIR
2424 Wentworth St.
Raleigh, N. C.
(Consultant)

OBIPEKIN AG BISCHOFSZELL (Schweiz)
Dr. Ing. W. Pilnik, Dir.
Bischofszell, Switzerland
(Fruit powders spray & vacumm dried.)

OREGON FREEZE-DRY FOODS, INC.
127 South Broadlbin
Albany, Oregon
B. W. Prinsen, Pres.
Ellis Byer, Mgr.
(Expect to be in business in 1964 as a custom drier. Foods to be dried include fish and other products of the Northwest.)

THE PILLSBURY CO.
311 Second St. S. E.
Minneapolis, Minn. 55414
John P. Barnes
(Liquid heat freeze-drying.)

POST DIV. OF GENERAL FOODS
Battle Creek, Mich.
(Freeze-dried fruits in dry cereals.)

PUCCINELLI PACKING, INC.
P. O. Box 430
Turlock, Calif.
Edward L. Fanucchi, Sales Mgr.
(Does not own sublimators. Contracts drying of vegetables, pieces, and powders. Distributes in Europe.)

SEXTON & CO.
Chicago, Ill.
(Distributes shrimp, mushroom pieces and stems. Market testing cottage cheese, fish patties and meat balls.)

SCIENTIFIC MENU FOOD PREP., INC.
1832 Johnson St.
Los Angeles 31, Calif.
Allifliated with Riverside Poultry Co., a subs. of Ralston-Purina Co.
Sal Castorina, Pres.
(On a custom basis--prepares, cooks, freezes, freeze-dries, and cans various foods as a service to food processors.)

STAL-LAVAL APPARAT AB
Linkoping, Sweden
Eric Stenstedt, Mgr.
(Manufactures vacuum equipment.)

THE CHUN KING CORP.
P. O. Box 206
5020 Roosevelt St.
Duluth 1, Minn.
Nathan G. Fox, V. P.
Research and Quality Control
(Processing wild rice, fruits, mushrooms, celery, and other materials on a pilot-plant basis.)

VOTATOR DIV. OF CHEMETRON CORP.
P. O. Box 43
Louisville 1, Ky.
H. E. Huber, Mgr. Sales Div.
Weld Conley, Dir. of Res.
(Design and manufacture equipment, a continuous vacuum belt dryer.)

U. S. ARMY NATICK LABORATORIES
Natick, Mass.
F. P. Mehrlich, Scientific Dir.
Justin Tuomy in charge of freeze-dry units.
(Has own sublimators for use in developing new foods and for supplying experimental tests for Armed Services.)

VILTER MFG. CORP.
2217 S. First St.
Milwaukee, Wis.
A. O. Vogel, Sales V. P.
(Manufactures and installs associated equipment including heat exchangers and refrigeration.)